# MIKE FLOOD

## 1D-2D Modelling

## User Manual

[DHI Software 2007]

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DHI Software

# MIKE FLOOD

## User Manual

# 1 INTRODUCTION

MIKE FLOOD is a tool that integrates the one-dimensional models MOUSE (MIKE URBAN), MIKE 11 and the two-dimensional model MIKE 21 into a single, dynamically coupled modelling system.

Using a coupled approach enables the best features of both a one -dimensional and two dimensional models to be utilised, whilst at the same time avoiding many of the limitations of resolution and accuracy encountered when using MIKE 11, MOUSE or MIKE 21 separately. Special features of MIKE FLOOD include:

- Momentum preservation through links
- Lateral links, enabling simulation of over bank flow from river channel to flood plain
- Comprehensive hydraulic structures package
- Implicit structure links
- Manhole links whereby the interaction of the sewer/storm water system may interact with the overland flow
- GIS integration
- Links possible along any alignment in MIKE 21 (not just horizontally or vertically)
- A graphical user interface standard (MIKE ZERO), allowing for easy data input and output as well as data preparation and analysis.
- A thorough on-line help system, user manual and technical reference documentation
- Support and continuing commitment from DHI Water and Environment

There are many advantages to using MIKE FLOOD and many model applications can be improved through its use, including:

- Flood plain applications
- Storm surge studies
- Urban drainage
- Dam break
- Hydraulic design of structures
- Broad scale estuarine applications

## 1.1 General Approach to Modelling with MIKE FLOOD

Consider the modelling systems that are integrated: MIKE 11, MOUSE and MIKE 21. By combining the systems the modeller can choose the best features of each and make the best model with these features.

For instance, consider the following abilities and limitations of MIKE 11:

- Has comprehensive and proven structure routines
- Can model very long or complicated river systems with little computational effort
- Can model one dimensional channel flow accurately
- Can be easily linked to rainfall and runoff programs
- Can simulate high velocity/super critical flow conditions
- Is one dimensional, so two dimensional effects such as cross-channel momentum is not possible
- Overland flow is difficult to model if flow paths are uncertain
- Requires more conceptualisation of flow conditions and more approximations
- Cannot easily simulate a coastal situation

Consider then MOUSE

- Has sophisticated descriptions for pipe flow and structures
- Can model highly complex pipe networks
- Can be easily linked to rainfall and runoff programs
- May be used to model open sections
- Is one dimensional, so a true two dimensional description of the overland flow is not possible
- Difficult to describe the complex interaction between overland flow and pipe flow

Finally consider MIKE 21:

- Two dimensional means more accuracy and better resolution

- Two dimensional, so overland flow can be simulated more accurately (also has efficient flooding and drying facility)
- Can simulate high velocity / supercritical flow conditions
- Can simulate a coastal situation
- Requires more computational effort

Additionally MIKE 21 rectangular grid has the following abilities and limitations

- Nested grid option means more flexibility with resolving features
- Fixed grid means less flexibility with resolving features
- Can be difficult to model narrow channels and flow paths, particularly if diagonal to flow
- MIKE 21 boundaries must be aligned with the grid (horizontal or vertical)

Finally the abilities and limitations of MIKE 21 flexible mesh are the following

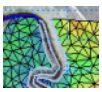
- Adaptive time step so that the time step of the 2D part adjusts to the dynamics
- Boundaries may have any alignment
- The river outline may be integrated in the mesh
- A fine mesh may be needed for resolving rivers and streams in mesh

Consider which of these features are most desirable for your application. How can you integrate MIKE 11, MOUSE and MIKE 21 to best utilise the most desirable features, while minimising the bad features? MIKE FLOOD enables this integration to be performed easily, but it is still the modeller who decides how best to design the integrated model. This manual will help you to make the decisions on how best to create a MIKE FLOOD simulation.

## 1.2 How to use this manual

MIKE FLOOD offers a range of flexibility. Through MIKE FLOOD the modeller can couple a pipe network, a river/stream network and an overland flow solver into one model. This flexibility is reflected in the range of modelling packages integrated in MIKE FLOOD namely MOUSE, MIKE 11 and MIKE 21. Further the latter may either be a rectangular grid or a flexible mesh version. A MIKE FLOOD model may run with only the MIKE 21 component or it may be augmented with a MIKE 11 and /or a MOUSE component. This flexibility is also reflected in the manual in that certain sections are only of importance if that specific component has been included. Throughout the manual the following icons will be used to indicate which sections are relevant for which components

MIKE 21 rectangular grid



MIKE 21 flexible mesh

MIKE 11

MOUSE

All link types are links between MIKE 21 and either MIKE 11 or MOUSE. Further MIKE 21 may either be a rectangular grid version or a flexible mesh version. The latter only possible if licensed. The various sections (unless indicated) are applicable to both versions of MIKE 21.

# 2 GENERAL DESCRIPTION

There are five different types of MIKE FLOOD links available. Four of these link MIKE 11 and MIKE 21 whereas the last type is reserved for linking a node/manhole in MIKE URBAN with one or more cells/elements in MIKE 21. Below follows a description of each of these link types.

## 2.1 Standard Link

This is the standard linkage in MIKE FLOOD, where one or more MIKE 21 cells/elements are linked to the end of a MIKE 11 branch. This type of link is useful for connecting a detailed MIKE 21 grid/mesh into a broader MIKE 11 network, or to connect an internal structure (with an extent of more than a grid cell) or feature inside a MIKE 21 grid/mesh. The link is explicit - see the scientific documentation for a full description. Potential applications are shown:

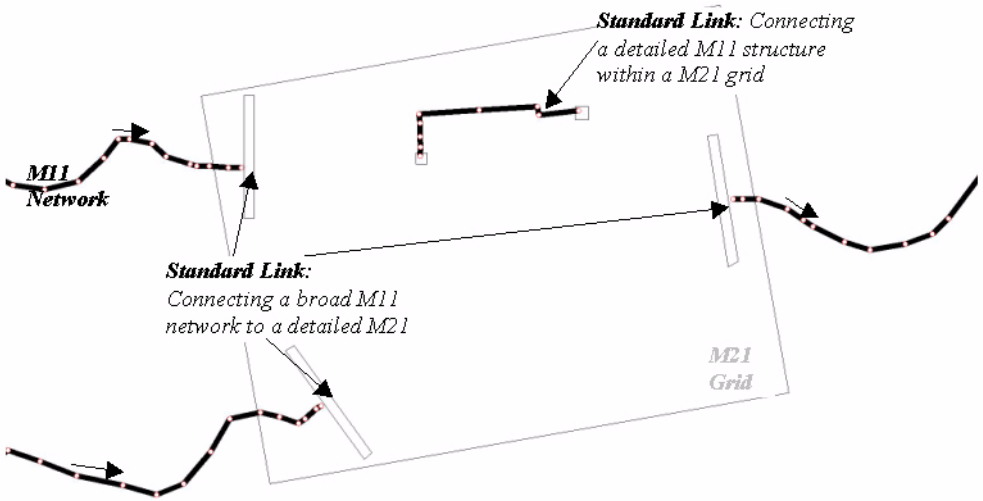
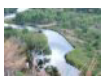

Standard Link: Connecting a detailed M11 structure within a M21 grid
M11 Network
Standard Link: Connecting a broad M11 network to a detailed M21
M21 Grid

*Figure 2.1 Application of Standard Links*

## 2.2 Lateral Link



A lateral link allows a string of MIKE 21 cells/elements to be laterally linked to a given reach in MIKE 11, either a section of a branch or an entire branch. Flow through the lateral link is calculated using a structure equation or a QH table. This type of link is particularly useful for simulat-

ing overflow from a river channel onto a flood plain. An example is shown:

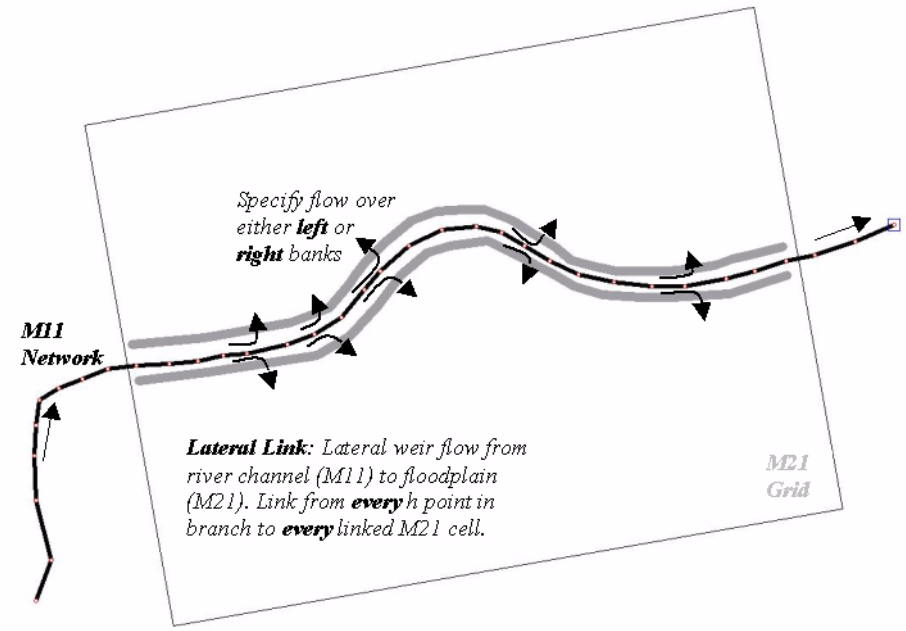

Specify flow over either left or right banks
M11 Network
Lateral Link: Lateral weir flow from river channel (M11) to floodplain (M21). Link from every h point in branch to every linked M21 cell.
M21 Grid

*Figure 2.2 Application of Lateral Links*

## 2.3 Structure Link (Implicit)

The structure link takes the flow terms from a structure in MIKE 11 and inserts them directly into the momentum equations of MIKE 21. This is fully implicit, so should not affect time step considerations in MIKE 21.

The structure link is useful for simulating structures within a MIKE 21 model. The link consists of a 3 point MIKE 11 branch (upstream cross-section, structure, downstream cross-section), the flow terms of which are applied to a MIKE 21 cell or group of cells. An example is shown:

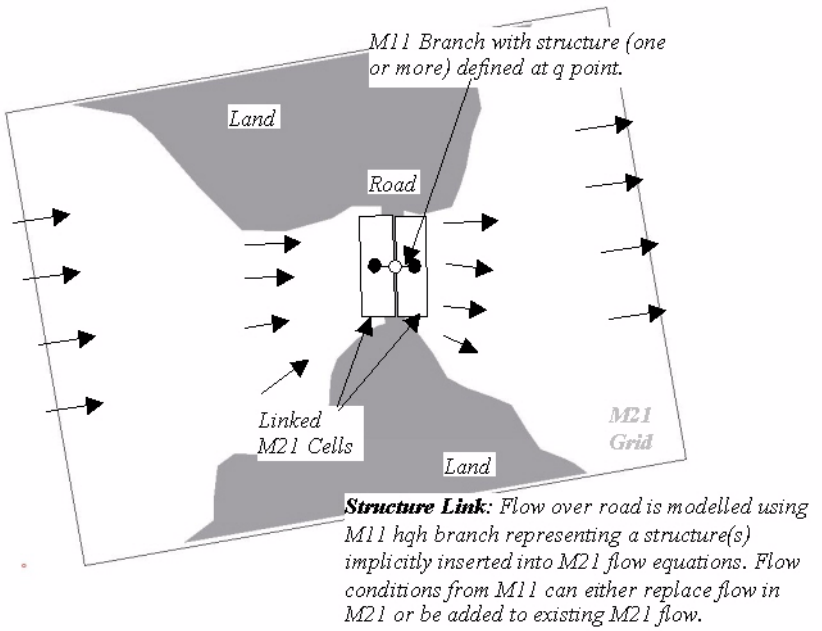

M11 Branch with structure (one or more) defined at q point.
Land
Road
Linked M21 Cells
Land
M21 Grid
Structure Link: Flow over road is modelled using M11 hqh branch representing a structure(s) implicitly inserted into M21 flow equations. Flow conditions from M11 can either replace flow in M21 or be added to existing M21 flow.

*Figure 2.3 Application of Structure Links. Only to be used for a rectangular grid.*

## 2.4 Urban Link

The urban link is designed to describe the interaction of water when a manhole is over topped or when overland flow enters a sewer/storm water network.

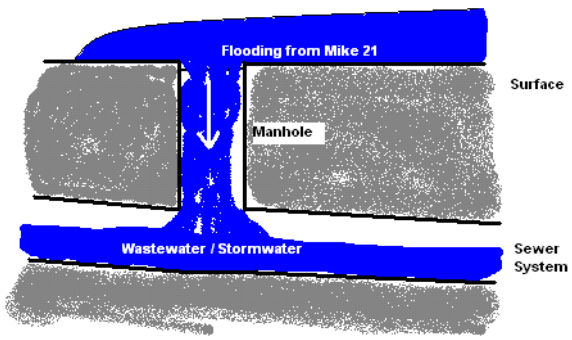



*Figure 2.4 Flooding from MIKE 21 into a non-surcharged sewer system.*

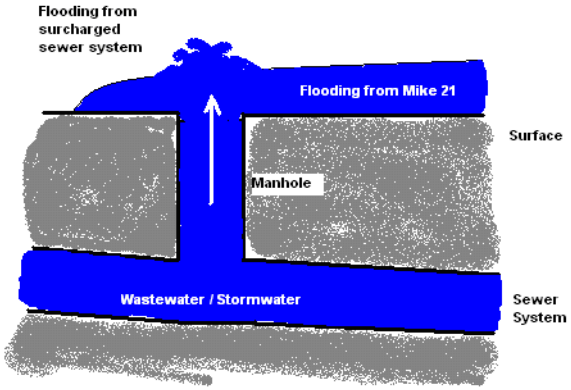



*Figure 2.5 Flooding from a surcharged sewer system into MIKE 21.*

The link is designed such that one or more cells/elements in MIKE 21 may be linked to a manhole/node in MOUSE.

## 2.5 Zero Flow Link (X and Y)

A MIKE 21 cell specified as a zero flow link in the x direction will have zero flow passing across the right side of the cell. Similarly, a zero flow link in the y direction will have zero flow passing across the top of the cell.

The zero flow links were developed to complement the lateral flow links. To ensure that flood plain flow in MIKE 21 does not travel directly across a river to the opposite side of the flood plain without passing through MIKE 11, zero flow links are inserted to block MIKE 21 flows. An alternative to using the zero flow links is to apply land cells which, depending upon grid resolution, may not be appropriate.

Another useful application of zero flow links is to represent narrow blockages on a flood plain, such as roads and levees. Rather than using a string of land cells, a string of zero flow cells can be used.

Note this link is only available when linking to MIKE 11.

# 3 APPLICATION DETAILS

Any combination of links can be used in a MIKE FLOOD simulation. All the information relating to the MIKE FLOOD links is contained in one file: the coupling file (file extension .COUPLE). The MIKE 11,MIKE 21 and MOUSE simulation files do not contain any information relating specifically to the links, except for:

- A dummy water level boundary condition must be applied at each standard or implicit link point in MIKE 11.

The coupling file interface is arranged with 4 sub-menus:

- Definition
- Standard / Structure Link Options
- Lateral Link Options
- Urban Link Options

Each of the sub-menus are described below.

## 3.1 Definition

The Definition menu contains information on the simulation files used in MIKE FLOOD and the general linkage definitions.

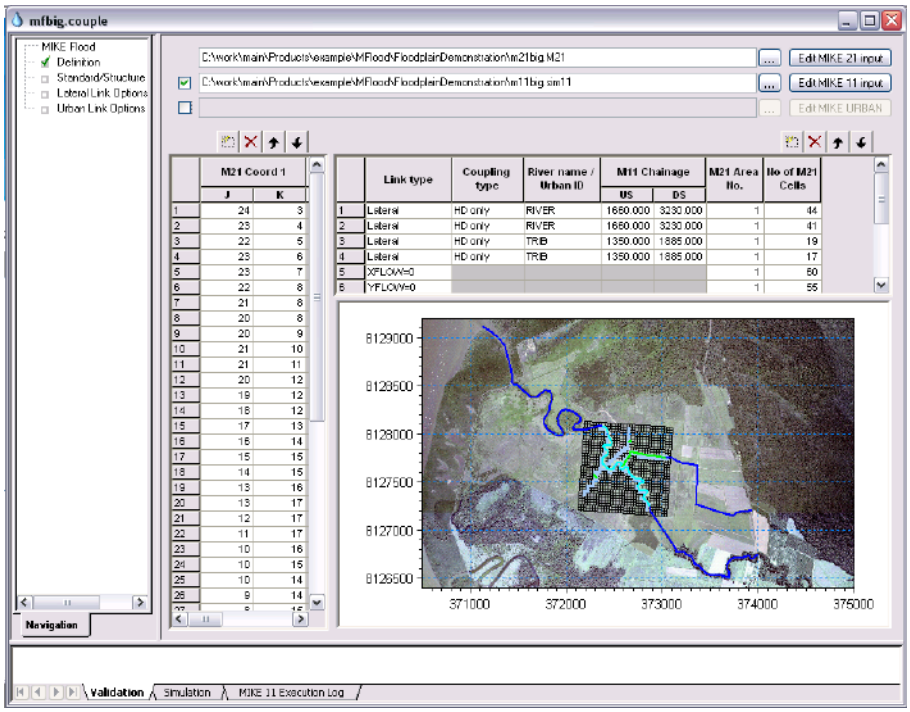



*Figure 3.1 Definition page of the MIKE FLOOD Editor. The set-up shown utilizes a rectangular grid.*

### 3.1.1 MIKE 21 File Name

A complete MIKE 21 setup should be established and tested prior to setting up MIKE FLOOD. The MIKE 21 setup is defined in the usual way using the respective editor. The path and file name of the resulting MIKE 21 File Name (*.m21 or *.m21fm) is provided in this menu. Note that the MIKE 21 engine is selected through the selection of the file type.

*Figure 3.2 MIKE 21 path name along with browse and edit buttons*

A button allows for browsing the parameter file. Furthermore, the “Edit MIKE 21 input” button allows for opening the existing MIKE 21 parameter file for further editing.

### 3.1.2 MIKE 11 File Name

It is optional whether a MIKE 11 model is to be used with MIKE FLOOD. If a link is to be established the tick box to the left of the file name field should be activated. If a MIKE 11 set-up is to be used with MIKE FLOOD the complete MIKE 11 setup should be established and tested. As with MIKE 21, this is done in the usual way using the appropriate editors. The path and file name of the MIKE 11 File Name (*.sim11) is provided in this menu.

*Figure 3.3 MIKE 11 simulation file path name along with browse and edit buttons. Note the tick box on the left which may be used to select or deselect whether a MIKE 11 set-up is to be included.*

A button allows for browsing the parameter file. Furthermore, the “Edit MIKE 11 input” button allows for opening the existing MIKE 11 simulation file for further editing.

### 3.1.3 Urban File name

MIKE FLOOD may be used with either MOUSE or MIKE URBAN(MOUSE engine). It is optional whether an urban model is to be used with MIKE FLOOD. If a link is to be established the tick box to the left of the file name field should be activated. If an urban set-up is to be used with MIKE FLOOD the complete urban set-up should be established and tested.

A button allows for browsing the parameter file. Furthermore, the “Edit MIKE URBAN” button allows for opening the existing MIKE URBAN set-up for further editing. If MIKE FLOOD is coupled with MOUSE the button is deactivated and the user must open the MOUSE set-up separately.

If a MIKE URBAN set-up is used in conjunction with MIKE FLOOD the set-up must be preprocessed before launching MIKE FLOOD. The preprocessing tool is located in the main menu bar under the run menu.

### 3.1.4 Overview of Links

The links may be of the following five different types:

- Standard links, the link is the connection between the end of a MIKE 11 branch and a series of MIKE 21 cells or element faces (if a flexible mesh is used).

- Lateral links, the link is the connection between one MIKE 11 river reach (within one branch) and a series of MIKE 21 cells/elements.
- Structure links, the link is the connection between the end of a MIKE 11 branch and a series of MIKE 21 cells (same as a standard link). However, two links are required for each structure link - one for each end of the structure. These “linked links” can only be one horizontal and/or vertical cell apart.
- Zero flow links (XFLOW=0 and YFLOW=0), the link is a list of cells in MIKE 21. There is no corresponding reference to the MIKE 11 simulation.
- Urban Link, the link is the connection between one or more cells in MIKE 21 and a node/manhole in MIKE URBAN/MOUSE.

*Table 3.1 An overview of the various links of their applicability*

| Link | Standard | Lateral | Structure | Zero flow | Urban |
|---|---|---|---|---|---|
| MIKE 11 | yes | yes | yes | yes | no |
| MOUSE | no | no | no | no | yes |
| MIKE 21 Rectangular | yes | yes | yes | yes | yes |
| MIKE 21 FM | yes | yes | no | no | yes |

Note that the number of links is not the total number of MIKE 21 cells/elements connected to the 1D models calculation points. To demonstrate, the setup shown in Figure 2.1 has five links, although each link contains several MIKE 21 cells/elements. There are two links shown in Figure 2.2, one for the left bank lateral flow and another for the right bank lateral flow. Figure 2.3 has two links, one upstream of the road and the other downstream of the road.

The list of links may be re-ordered, augmented or reduced using the following tool buttons

Add a new link. The link will be augmented to the list.

Remove an existing link.

Move an existing link up the list.

Move an existing link down the list.

Please note that the 'insert' and 'delete' keys on the keyboard cannot be used for inserting and deleting links in the overview.

### 3.1.5 Link Type

The link type defines the type of link:

- Standard (E) - the E indicates that the link is explicit
- Lateral
- Structure (I)- The I indicates that the link is implicit
- XFLOW=0
- YFLOW=0
- Urban

The link type is set from the combo box.

### 3.1.6 Coupling Type

The coupling type can be:

- HD only - the link will only transfer hydrodynamic information (requires HD simulation defined in both linking models)
- AD only - the link will only transfer advection-dispersion information.
- HD and AD

The coupling type is selected through the use of a combo box.

Note that the AD link is only possible between MIKE 11 and MIKE 21 rectangular gridand requires that the AD simulation is defined (and licensed) in MIKE 11 and MIKE 21. Presently the AD linking is not available for the Urban link.

### 3.1.7 MIKE 11 River Name/Node ID and Chainage

- If using a standard or structure link, M11 river name is the MIKE 11 branch with the link and 1st / US M11 chainage is the chainage of the MIKE 11 boundary point. Note that this is not necessarily the upstream chainage in the branch (it may well be the downstream chainage) - the label "US" refers to lateral link specifications only. The same boundary location should exist in the MIKE 11 boundary file (*.bnd11) and be defined as a water level boundary in the initial MIKE 11 set-up. This boundary condition specification is only to maintain consistency between MIKE FLOOD and MIKE 11 - it will be overridden by information from the link during simulation. Furthermore, if performing an AD simulation then an open concentration boundary should be specified (not the Time Series dependent option).
- If using a lateral link, M11 river name is the MIKE 11 branch with the link. US M11 chainage and DS M11 chainage define the upper and lower extents of the lateral link, so all MIKE 11 calculation points between the specified chainages will be linked to MIKE 21. Unlike the standard links, no further adjustments need to be made to the MIKE 11 boundary definitions. Please note that the lateral link must span a reach in the river which includes at least one grid point (typically a cross section).
- For zero flow links, no MIKE 11 information is required.
- For urban links an urban ID is required. This urban ID depends on the type of urban link. That is if the link is to an inlet or an outlet the node ID must be supplied. For a link to a pump the urban ID constitutes the pump ID and a for a link to a weir the weir ID is needed. The chainage column is not applicable.

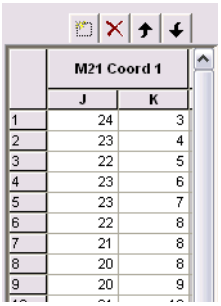
| | Link type | Coupling type | River name / node ID | M11 Chainage | | M21 Area No. | No of M21 Cells |
|---|---|---|---|---|---|---|---|
| | | | | US | DS | | |
| 1 | Lateral | HD only | river | 2457.000 | 3560.000 | 1 | 1 |
| 2 | Structure(I) | HD only | culvert | 0.000 | | 1 | 1 |
| 3 | XFLOW=0 | | | | | 1 | 1 |
| 4 | YFLOW=0 | | | | | 1 | 1 |
| 5 | Standard(E) | HD only | tributary | 2300.000 | | 1 | 1 |
| 6 | Urban | HD only | manhole | | | 1 | 1 |

*Figure 3.4 The overview of links. The 6 possible link types are represented. Note that for a lateral link two chainages are required whereas for structure and standard links only one chainage is required. The XFlow=0 and YFlow=0 do not require any MIKE 11 data since their purpose is purely to block flow in the 2-dimensional grid. Finally the Urban link requires a node ID of the manhole.*

### 3.1.8 MIKE 21 Area Number

This option is available for applications with nested MIKE 21 rectangular grids. The default value (for un-nested grids) is 1.Thus the M21 Area No. must correspond to the identifier in the MIKE 21 parameter file.

### 3.1.9 MIKE 21 Coordinates



| | M21 Coord 1 | |
|---|---|---|
| | J | K |
| 1 | 24 | 3 |
| 2 | 23 | 4 |
| 3 | 22 | 5 |
| 4 | 23 | 6 |
| 5 | 23 | 7 |
| 6 | 22 | 8 |
| 7 | 21 | 8 |
| 8 | 20 | 8 |
| 9 | 20 | 9 |

*Figure 3.5 The list of cells used for a specific link (link number 1). The four buttons at the top are used in the same way as the ones described for the link overview section*

There is a separate table available to enter a list of coordinates defining the MIKE 21 cells. The cells are organised in an ordered list. The linked cells can be horizontal, vertical, or any other alignment. Remember that if using a lateral link the cells should be in the same sequence as increasing chainage specified in MIKE 11. Further note that MIKE FLOOD only allows lateral linked cells which are ordered such that any two sequential cells are adjacent. Thus a sequence $(J_1,K_1)$, $(J_2,K_2)$ must satisfy two of the following equations:

$$\begin{aligned} K_2 &= K_1 - 1 \\ K_2 &= K_1 + 1 \\ J_2 &= J_1 - 1 \\ J_2 &= J_1 + 1 \\ J_2 &= J_1 \\ K_2 &= K_1 \end{aligned} \tag{3.1}$$

The valid cells are illustrated in the figure below.

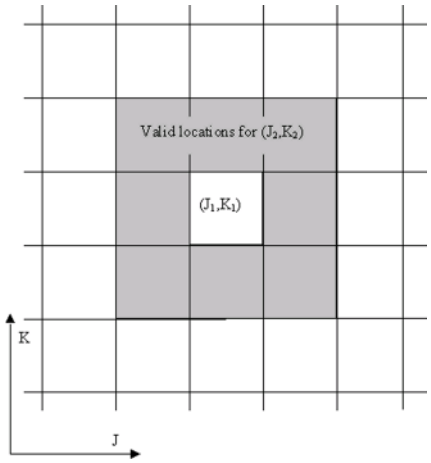
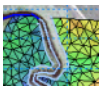



*Figure 3.6 Valid locations for a cell ($J_2$,$K_2$) being adjacent to cell ($J_1$,$K_1$)*



If the flexible mesh version of MIKE 21 is used the coordinates table holds the actual coordinates of the linkage line along with a third column containing chainage values along the river. The chainage column controls how the linkage points are mapped onto the river.

## 3.2 The graphical layout

MIKE FLOOD includes a graphical view that displays the bathymetry, the modelled MIKE 11 branches, the MIKE URBAN or MOUSE pipe network along with additional image files. The graphical view gives a clear overview of the location of the links in MIKE FLOOD. Further the graphical view has a number tools for automatically selecting the linkage points/cells in MIKE 21.

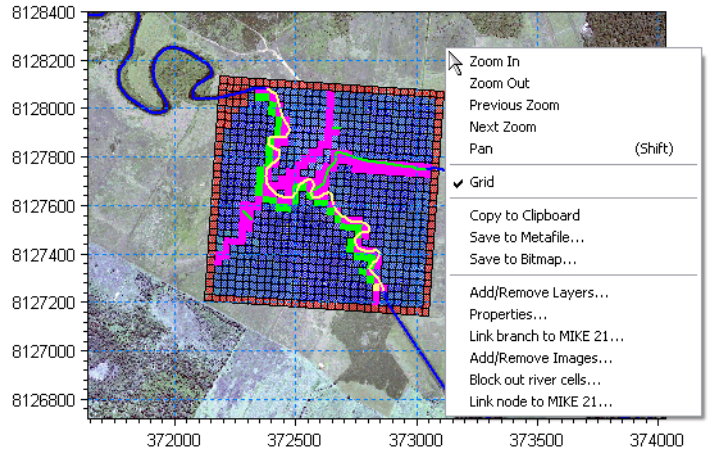



*Figure 3.7 The graphical layout of MIKE FLOOD. Note the drop down list that may be accessed by right clicking. The figure illustrates the use of a rectangular grid version of MIKE 21.*

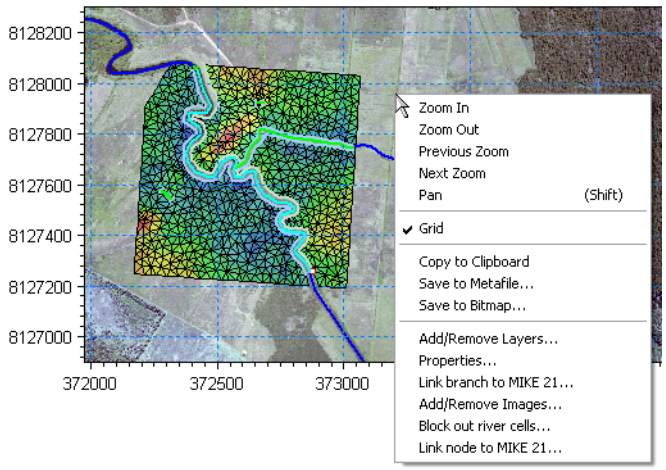



*Figure 3.8 The graphical layout of MIKE FLOOD. The figure illustrates the use of a flexible mesh version of MIKE 21. The 'Block out river cells' does not apply to a flexible mesh.*

Right clicking on the graphical view of MIKE FLOOD displays a number of options. The following options are available through the graphical view:

- It is possible to zoom in and out in the graphical view. To return to the full view right click and choose Zoom extents. Note that the extent of the graphical view is governed by the last selected file either MIKE 21, MOUSE or MIKE 11. Thus to ensure that both set-ups can be viewed at the same time it may be necessary to adjust the working area of the MIKE 11 and the MOUSE set-up.
- It is possible to pan in the graphical view. To do this click in the graphical view and either right click and select the pan option or use the shift key in conjunction with the left mouse button.
- The graphics may be exported to the clipboard or saved in a bitmap or a metafile format.
- Selection of layers (bathymetry files and MIKE 11 nwk file) to be included in the graphical view.
- The display properties for the graphical view are accessed through this sub-menu.
- Branches may be automatically linked to the MIKE 21 set-up.
- Images may be added or removed from a set-up.
- Cells lying in the main river bed between the left and the right levee may be blocked out. This may be done to ensure that mass is not double counted. Note this feature is only available for the rectangular grid version of MIKE FLOOD.
- Nodes in the urban set-up may be linked to the MIKE 21 grid cells/elements.

### 3.2.1 Information on the individual cells

To obtain information on the individual cells simply click on a cell in the graphical view. The (j,k) coordinates will be displayed in the lower information bar of MIKE Zero (see Figure 3.9).

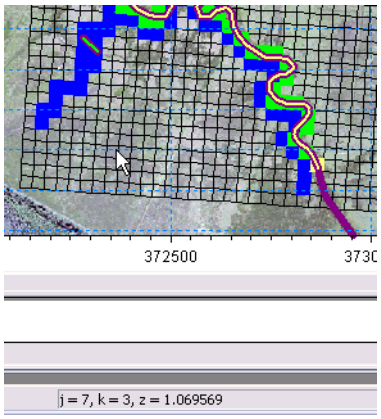



*Figure 3.9 Clicking a particular cell displays the information in the lower MIKE Zero bar.*

### 3.2.2 Add/Remove Layers ...

The graphical view displays all bathymetry files found in the MIKE 21 file along with the branches found in the MIKE 11 network file. Additional bathymetry files and MIKE 11 network files may be displayed if needed. The sub-menu has two tabs. The first of these (Figure 3.10) controls the model files to be displayed and the second controls the display order of all files including images and colour legends

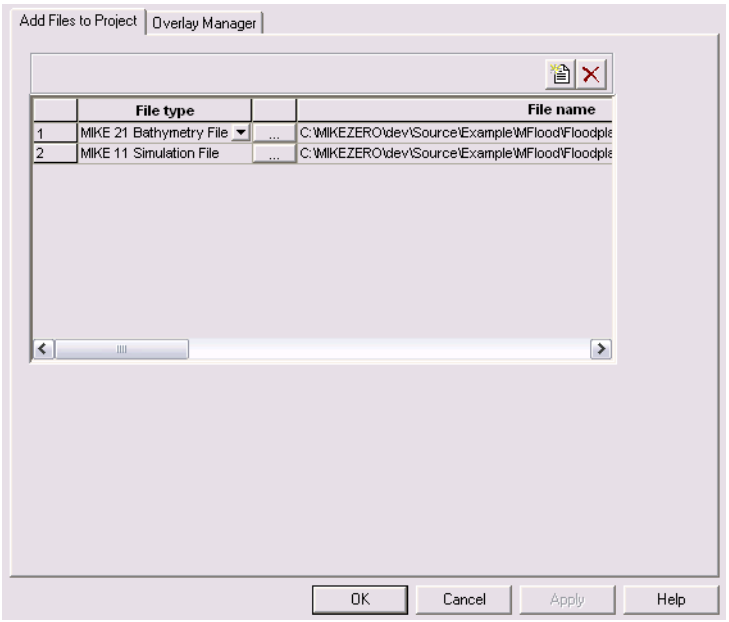



*Figure 3.10* *Files included in the set-up. The files from the coupled set-ups are included by default. Additional bathymetry files, mesh files and MIKE 11 or Urban files may be added.*

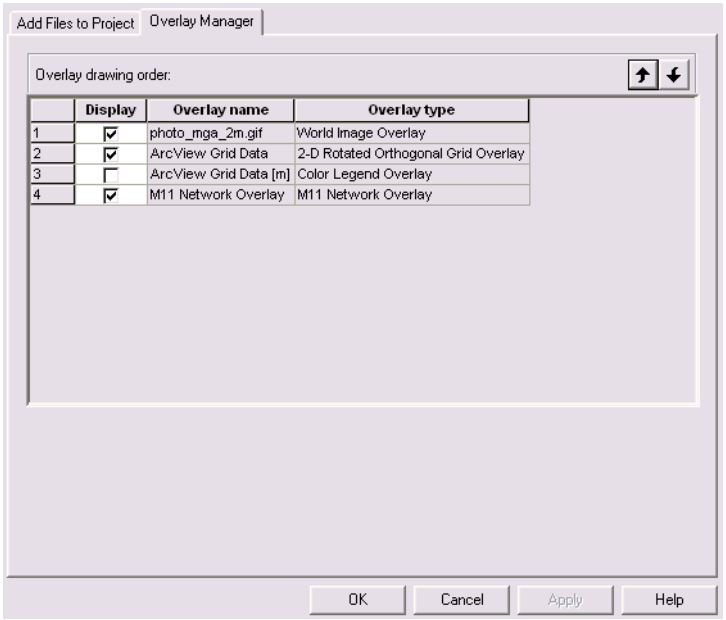



*Figure 3.11 The overlay manager controlling which graphical themes to be displayed as well as the order of the themes. The latter may be changed through the use of the two arrow buttons in the upper right hand corner.*

### 3.2.3 Link river branches to MIKE 21

The MIKE FLOOD interface has tools for the automatic selection of linkage to MIKE 21. Two main linkage types are available

- Lateral links
- Standard/structure links

The lateral link requires the user to supply the river branch name and the topo-ID used along with the reach stations. The user also selects whether the linkage should be along the centerline or the line made out by the left and right levee. Based on the information entered by the user the tool automatically selects either

- the MIKE 21 grid cells intersected by the left/right or centre line for the rectangular grid version
- or in the case of the flexible mesh the coordinates of the left and the right end points of the cross sections.

The standard/structure link only requires the user to specify the branch name, the topo-ID and whether the link is to be applied at the upstream (lowest chainage) or the downstream end (greatest chainage).

Once the links have been established the location of the links may be inspected by stepping through the links in the cell table on the left whereby the active cell/point is highlighted in the graphical view.

*Figure 3.12 The 'link branch to MIKE 21' sub-menu. Note that for a lateral link two chainages are required whereas for standard/structure links only information on whether the link is to be applied to the upstream or the downstream end of a branch is needed.*

### 3.2.4 Add/Remove Images

This menu controls the images to be shown. The following files are possible to display

- graphical image files: *.bmp, *.jpg and *.gif.
- GIS shape files: *.shp.
- XYZ ASCII files: *.xyz
- MIKE 11 network files: *.nwk11
- Enhanced metafiles: *.emf

For each of the different files some of the display settings may be edited by clicking the 'edit' button found in the same row as the image file to be edited.

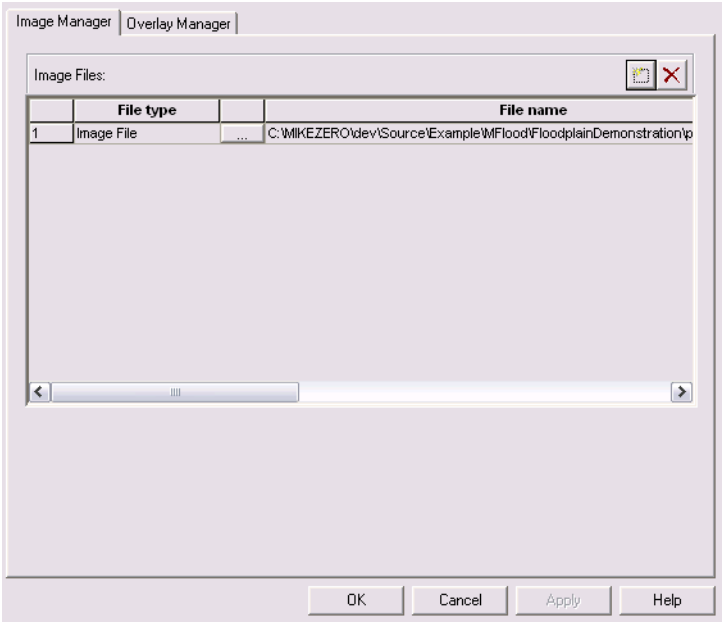



*Figure 3.13 The image manager. Images may be added or removed using the two buttons in the upper right hand corner. The second tab is identical to the overlay manager found in the 'Add/Remove Layers' menu shown in Figure 3.11.*

### 3.2.5 Block out river cells...

If the widths of the rivers in a set-up are more than one cell size wide then it may be appropriate to block out the cells lying within the main river bed. Hereby one ensures that the water body within the main river is not included twice in the coupled model.

The blocking out of cells requires the user to edit the MIKE 21 bathymetry in the grid editor. The blocking out is done by setting the cell level equal to the land value used in the particular bathymetry.

The MIKE FLOOD interface can (based on the cross sectional widths) select the cells lying within the main river. The selection is exported to a so-called selection-file. This selection-file may then subsequently be used in the grid editor to edit the level of cells within the main river bed.

To access the selection tool for blocking out cells simply right click in the graphical view and select the 'Block out river cells' menu item. The dialog that appears is shown in Figure 3.16.

The tool is applied to each river reach separately. The reach is selected based on the river name, the topo-ID and the upstream/downstream chainages. The cells lying within the left and right linkage lines are exported to the file specified in the selection file field. Note that the selection file is a .dfs2 file containing the 2D grid with a value of 1 in all selected fields.

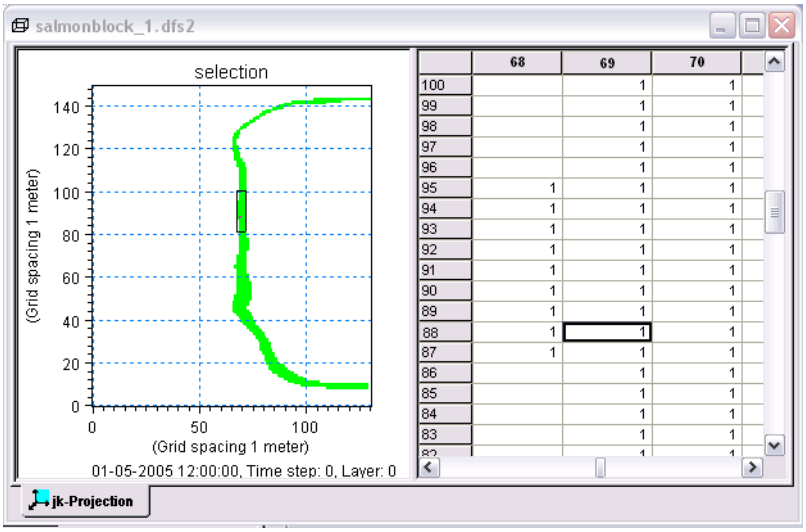



*Figure 3.14 A selection file opened in the grid editor of MIKE Zero.*

Since MIKE FLOOD may be used with nested grids (provided a nested MIKE 21 is available) the selection tool may export multiple files for the same river reach i.e. a selection file for each grid in the MIKE 21 set-up. To distinguish between these different selection files MIKE FLOOD inserts the area number at the end of the file name e.g. if the file name 'selection.dfs2' is chosen the actual selection files are named 'selection_1.dfs2', selection_2.dfs2, etc. depending on the number of nested grids in the MIKE 21 set-up.

### Step by step procedure for blocking out cells in the river bed

1 In the MIKE FLOOD graphical view right click and select the ‘Block out river cells...’ option (see Figure 3.15).

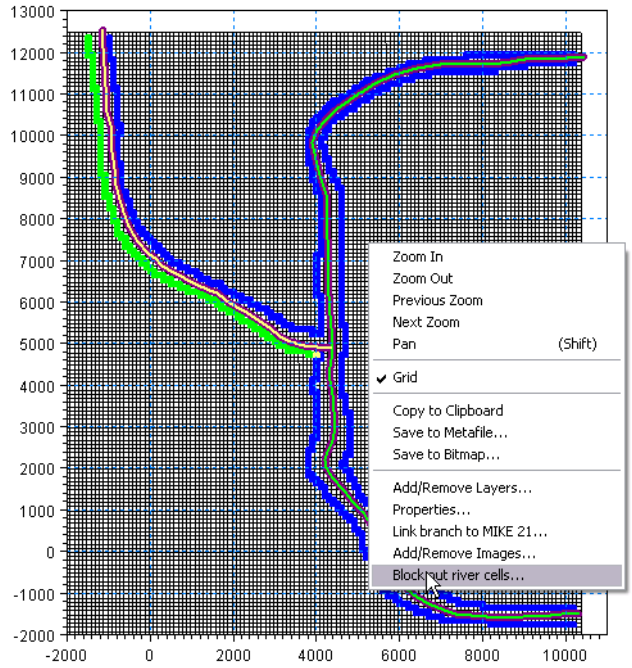



*Figure 3.15 Accessing the blockage tool in MIKE Flood.*

2 In the dialog that appears select the river reach that the blockage is to be applied to. Please ensure that the river name is typed correctly and that the correct topo-ID is also supplied. If chainages are given which are beyond the river reach the values are modified to coincide with the reach ends. Also supply the name to be used for the selection file including the .dfs2 extension (see Figure 3.16).

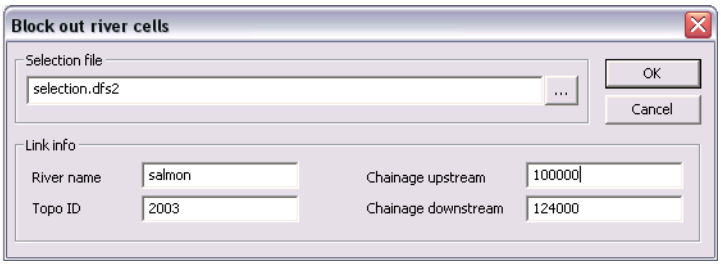



*Figure 3.16 The dialog box for selecting which cells to block out in the MIKE 21 bathymetry.*

3 Open the bathymetry file used in the MIKE 21 set-up. The file may be accessed through the 'file -> open' menu of MIKE Zero or through the MIKE 21 interface by clicking the 'view' button found in the bathymetry menu. The latter automatically opens the bathymetry file in the grid editor.

4 With the bathymetry file as the active window in MIKE Zero it is possible to access the menu 'Tools -> Load Selection' found in the main menu bar of MIKE Zero. At this point you are prompted for the selection file. Browse for the selection file previously generated remembering that the file name has been augmented with a number indicating the area number. The selected cells will by now be highlighted in the grid editor.

5 Access the 'set value' through the 'Tools' menu of the main MIKE Zero tool bar and provide the land value of the dfs2 file in the active box (see Figure 3.17).

6 Save the bathymetry file under a different name to ensure that the original data is not overridden.

7 In the MIKE 21 editors bathymetry menu select the new edited bathymetry.

8 Repeat the procedure for all rivers requiring blocking out of cells.

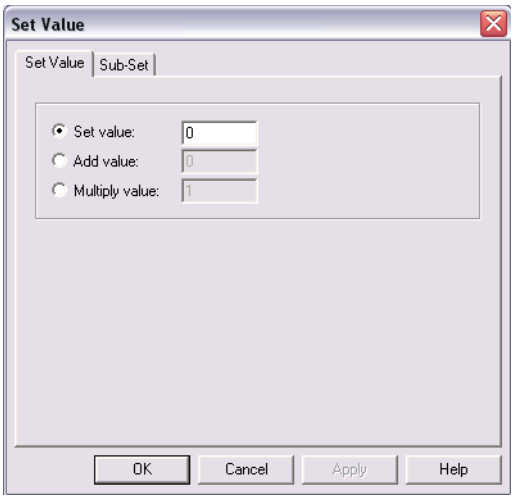



*Figure 3.17 The set value dialog. Choose the appropriate land value for the dfs2 file.*

### 3.2.6 Link node to MIKE 21 ...

Manholes may be linked to MIKE 21 through the use of this tool. The tool can automate the linking of all manholes to the MIKE 21 grid/mesh or the user may select individual manholes to link based on either a drop down list or a node selection file (*.nse).

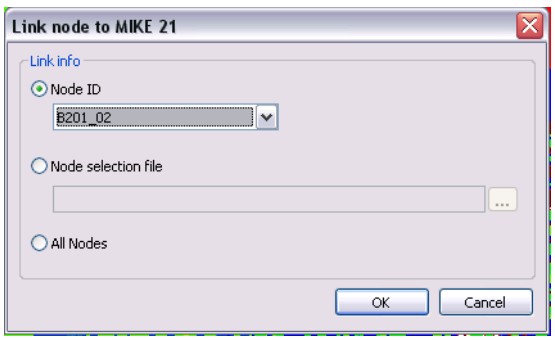



*Figure 3.18 The link node menu. The user can either link all manholes in the set-up or a selection hereof by the use of either a node selection file or through the drop down list of node IDs.*

## 3.3 Options for Standard / Structure Links

The options listed here are only applicable for Standard and Structure links.

| | Link type | Mom Fact | Ext Fact | Add/Replace Flow | Depth Adjst | Activation Depth(min) | Activation Depth(max) | Implicit relaxation factor |
|---|---|---|---|---|---|---|---|---|
| 1 | Lateral | | | | | | | |
| 2 | Lateral | | | | | | | |
| 3 | Lateral | | | | | | | |
| 4 | Lateral | | | | | | | |
| 5 | XFLOW=0 | | | | | 0.000 | 0.000 | |
| 6 | YFLOW=0 | | | | | 0.000 | 0.000 | |
| 7 | Structure(I) | | | Replace | No | | | 1.000 |
| 8 | Structure(I) | | | Replace | No | | | 1.000 |
| 9 | Structure(I) | | | Replace | Yes | | | 1.000 |
| 10 | Structure(I) | | | Replace | Yes | | | 1.000 |

*Figure 3.19 Overview of options for standard and structure links. Note that the first column is carried over from the Definition page and cannot be edited*

### 3.3.1 Mom Fact

This is an abbreviation for Momentum Factor. The Momentum Factor is applied to the momentum terms in MIKE 21 for standard links. A value of 1 means full momentum transfer through the link, while a value of 0 means that momentum transfer is not guaranteed.

Note that even if the factor is set to 0, the source term applied to the continuity equation still creates some momentum. While this is sufficient in cases where conservation is not critical (such as over weir structures or for very large 2D cell size relative to the river flow capacity), it will not be accurate enough for all cases. On the other hand, in some instances model stability may be improved by removing the momentum terms.

Momentum is disabled for the lateral links because of the conceptual difficulties associated with lateral flows in a 1D model.

For the structure links, momentum is preserved via the implicit terms and this parameter is not applicable.

### 3.3.2 Ext Fact

This is an abbreviation for Extrapolation Factor. For standard links, the extrapolation factor has a default value of 1.5. This factor controls the time predictor in MIKE 11, which establishes MIKE 21 link values for the next time step. If factor is set to zero, the same value at n+1 will be used as

at n. Note! If the last q point in the linked branch is a structure, this factor is set to zero by the calculation kernel.

The extrapolation factor is not applied for lateral links or for structure links. For more information, see the scientific documentation (7.1 Hydrodynamics - Standard Links *(p. 65)*).

### 3.3.3 Add / Replace Momentum Terms

This option is available for structure links.

- If the momentum terms are replaced, flow conditions calculated in MIKE 11 override flow conditions in the MIKE 21 cell.
- If momentum terms are added, the flow conditions calculated in MIKE 11 are added to the flow conditions in the MIKE 21 cell.

To illustrate, consider a situation where a weir structure in MIKE 11 represents a road embankment in a MIKE 21 grid (similar to that shown in Figure 2.3). The MIKE 11 structure flow would replace the MIKE 21 flow conditions.

Next, consider the same situation except with a culvert located under a section of the road. The culvert structure would be modelled in MIKE 11 (in a separate branch to the weir) and added to the flow conditions in the MIKE 21 cells. As long as this culvert structure link is listed in the coupling file after the weir structure link, both weir and culvert flow would be included in MIKE 21.

Consider a third possibility, where the road embankment is instead simulated as normal MIKE 21 cells. This is a reasonable practice (the upwinding facility automatically implemented in MIKE 21 has been shown to simulate weir flow well). In this situation the weir structure in MIKE 11 would not be required, and the culvert structure flows would be added to the MIKE 21 cells.

Note: the add / replace options mean that the order in which structure links are listed in the couple file will affect the model behaviour. By specifying “Replace” in a link, all previous link inflows from previous links will be overridden. Also note that MIKE 11 can handle composite structures e.g. a culvert and a weir at the same location. This may be used to handle a complex situation with flow both over topping and flowing under an embankment. The definition of such a structure is handled in MIKE 11 and does not require two explicit couplings in the MIKE FLOOD interface.

### 3.3.4 Depth Adjustment

If depth adjustment is active, flow through a link is distributed into the MIKE 21 cells according to the water depth in those MIKE 21 cells. This is considered appropriate for links on natural terrain or channels, but may not always be applicable for structures.

### 3.3.5 Activation Depth (Minimum and Maximum)

The activation depth is valid only for the *zero flow (XFLOW=0 and YFLOW=0) links*. If specified then these links will be turned off once the activation depth is reached. A maximum and minimum value is available to gradually apply the flow conditions over a range to minimise instabilities. Note that the feature is only available with a MIKE 11 link.

If the minimum and maximum values are set to zero, the activation depth facility is inactive.

### 3.3.6 Exponential Smoothing Factor

The parameter introduces an exponential smoothing of the water level values transferred from the MIKE 21 grid to the structure. A value of 1 indicates no smoothing whereas a value closer to 0 creates strong smoothing in the model.

The smaller the value the greater the smoothing will be. The parameter impacts the dynamics by smoothing out steep gradients (in time) through the links.

In general the exponential smoothing factor should be adjusted when a structure exhibits unstable behaviour (oscillates wildly). In general the following approach should be followed if a structure shows instability

1) Set the exponential factor to 0.2 – 0.4

2) Run the model

3) If a structure still “misbehaves” (i.e causes a blow-up OR the discharge hydrograph is very 'noisy') then check the results file, the MIKE 11 structure setup, MIKE 21 topographic grid, the coupling, etc. for problems, and inconsistencies.

4) Rerun the model if changes are made.

5) If the structure still “misbehaves” then the smoothing factor may be further reduced. Note that a small smoothing factor will cause a time lag in the transfer of the values from the 1D to the 2D component. As a rule of thumb the time scale at which the model changes over should be a factor

greater than the time lag caused by the smoothing factor. As an estimate for the latter the following expression may be used

$$T = \Delta t \frac{\log f}{\log(1-\alpha)} \tag{3.2}$$

where $f = 0.001$, $\alpha$ is the smoothing factor and $\Delta t$ is the model time step. The estimate is based on the time it takes for an initial deviation in the MIKE 11 and MIKE 21 water level to be reduced to within 0.1 % of each other.

6) Rerun the model.

7) If a small value of the smoothing factor is required, you need to satisfy yourself that the results are reasonable and the results for the overall model have not been significantly delayed.

## 3.4 Options for Lateral Links

Except for the depth tolerance the options listed in this menu are only relevant for lateral links.

| | Link type | M11 | Structure | | | | | | | External Files | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Side | Method | Type | Source | Depth Tol. | Weir C | Fric(n) | FLC | Geometry | | QH Table | |
| 1 | Lateral | Right | Cell to Cell | Weir 1 | HGH | 0.100 | 1.838 | 0.050 | | | .. | | .. |
| 2 | Lateral | Left | Cell to Cell | Weir 1 | HGH | 0.100 | 1.838 | 0.050 | | | .. | | .. |
| 3 | Lateral | Right | Cell to Cell | Weir 1 | HGH | 0.100 | 1.838 | 0.050 | | | .. | | .. |
| 4 | Lateral | Left | Cell to Cell | Weir 1 | HGH | 0.100 | 1.838 | 0.050 | | | .. | | .. |
| 5 | XFLOW=0 | | | | | | | | | | .. | | .. |
| 6 | YFLOW=0 | | | | | | | | | | .. | | .. |
| 7 | Structure(I) | | | | | | | | | | .. | | .. |
| 8 | Structure(I) | | | | | | | | | | .. | | .. |
| 9 | Structure(I) | | | | | | | | | | .. | | .. |
| 10 | Structure(I) | | | | | | | | | | .. | | .. |

*Figure 3.20 The overview for lateral links. Note that the link type is carried over from the 'Definition' page and cannot be edited*

### 3.4.1 Side of River

Side of river defines whether the lateral link is a link on the left bank or the right bank of the river channel.

- Left bank is equivalent to Marker 1 in the MIKE 11 cross-section editor

- Right bank is equivalent to Marker 3 in the MIKE 11 cross-section editor

### 3.4.2 Method

The structure method defines the method by which flow is distributed between MIKE 11 and MIKE 21:

- The CELLTOCELL method performs a flow calculation for each individual point in the defined structure. Each calculated flow is then redistributed to MIKE 21 and MIKE 11. This means that the number of MIKE 11 points doesn't necessarily have to match the number of MIKE 21 cells.
- The SIMPLE method performs a single calculation of flow, then distributes that flow to each MIKE 21 cell and/or MIKE 11 computation (h) point.

The CelltoCell method is the default and is the only one available if linking with a flexible mesh.

### 3.4.3 Structure Type

The structure type defines the type of flow calculation to be performed:

- *WEIR1*: MIKE 11 Weir Formula 1 with friction term included.
- *WEIR2H*: MIKE 11 Weir Formula 2 (Honma) with friction term included.
- *QHTABLE*: A QH table is used, read in from an external file. Note that if using a CELLTOCELL method, the Q in the QH table is the flow per unit width.
- *QDTABLE*: A QH table is used, except that water depth above the structure invert is used rather than water level. This could be useful if using a CELLTOCELL method with different bed levels in each cell but similar flow characteristics. This is read in from an external file.
- *FORMLOSS*: Standard velocity head form loss equation ($\Delta h = \zeta v^2/2g$). The form loss coefficient can include a friction component.

The WEIR1 type is the default. See the Scientific Documentation for more information.

### 3.4.4 Source

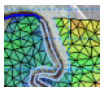
The structure source determines where the levee level geometry information comes from. Depending on whether a rectangular grid or a flexible mesh is used the lateral links are treated slightly differently.

### Rectangular Grid

- M11: Structure points are defined at each river computation (h) point. The cross-section left or right bank markers (marker 1 or marker 3) are extracted from the cross-section database and used as the link structure bed levels. Bank levels at h points without a cross-section are interpolated.
- M21: Structure points are defined at each MIKE21 cell. Bed levels from MIKE21 cells are used as the structure bed levels.
- HGH: Structure points are defined at either each MIKE 11 computational h point or each MIKE 21 cell, whichever has the highest resolution. The structure bed levels are the highest of the MIKE 11 bank markers and the MIKE 21 cells.
- EXT: Information is read from an external ASCII file.

The HGH source type is the default

### Flexible mesh



For the flexible mesh the lateral link is divided up into segments. Each segment being defined by two consecutive set of coordinates for the lateral link. A discharge is evaluated across each segment and distributed in MIKE 11 according to the chainage values for the segment end points. The source parameter only controls the from where the levee height should be extracted:

- M11: The levee height is determined from the bank markers in MIKE 11.
- M21: The levee height is defined by the topography in MIKE 21.
- HGH: Takes the max of the MIKE 21 topography and the MIKE 11 bank markers.
- EXT: The levee height is supplied in an external ASCII file.

The HGH source type is the default.

### Note

The levee height is not allowed to be below the MIKE 21 topography (at the linkage point) nor below the bed level in MIKE 11. Thus if the selection is such that this occurs MIKE FLOOD will use the limiting value.

## *3.4.5 Depth Tolerance*

This parameter is used to smooth out the transition when the flow over the lateral link changes direction. The parameter is also available for the implicit structures. In this case the parameter is used to describe the water

level difference across the structure at which point the discharge gradients are gradually suppressed. If such a suppression is not applied the model may experience numerical instability. The suppression varies with the water depth and is only active when the water level difference is less then the depth tolerance.

### 3.4.6 Structure Coefficients

Coefficients controlling flow through the link structure include the weir coefficient (default = 1.838 $m^{1/2}/s$), the weir exponent coefficient (default = 1.5), the Manning's n friction coefficient ($m^{1/3}/s$) and the form loss coefficient. Note that friction can be included in the weir equations - see the scientific documentation for more information.

### 3.4.7 External Files

If the structure source is EXT, an external file is specified. If the structure type requires a QH table to be read, a qh external file is specified. The formats of both files are shown in Table 3.2 and Table 3.3.

*Table 3.2 Format of External Structure File*

| File Input Example | Description |
|---|---|
| // External file from GIS<br>4<br>0.0 2.0<br>100.0 0.0<br>500.0 0.0<br>1000.0 2.0 | '//' is a comment marker - as many comment lines as desired can be included in this file.<br>Line 1: Number of entries.<br>Line 2 onwards: column entries, space delimited - first column is chainage, second column is bed level (m). |

*Table 3.3 Format of External QH File*

| File Input Example | Description |
|---|---|
| // HQH file<br>5 3<br><br>0.0 1.0 2.0<br>0.0 0.1 0.2 0.3<br>1.0 0.3 0.3 0.3<br>2.0 0.4 0.5 0.7<br>3.0 0.9 1.9 2.9<br>5.0 10.0 20.0 50.0 | '//' is a comment marker - as many comment lines as desired can be included in this file.<br>Line 1: Number of upstream levels (rows = nr) and number of downstream levels (columns = nc), space delimited.<br>Line 2: List of nc values of downstream levels (m), space delimited.<br>Line 3 onwards (nr lines): List of nc values of upstream level, then nc values of discharge ($m^3/s$), space delimited.<br>Notes:<br>• If QHTABLE, levels are water level (m)<br>• If QDTABLE, levels are water depth (m)<br>• If CELLTOCELL, discharge is flow per unit width ($m^2/s$) |

Note that values are space delimited.

### 3.4.8 Additional lateral linkage feature

MIKE FLOOD includes a feature for analysing the invert levels of lateral links. The feature works by generating an ASCII file containing the invert levels of the lateral links. This file may be directly imported into the cross section editor.

Internally within MIKE FLOOD lateral links are treated differently depending on whether a rectangular grid or a flexible mesh is used.

#### Rectangular Grid

When using the rectangular grid lateral links are treated in the following way

- The h-grid points within the linked river reach are identified.
- The linked MIKE 21 cells are given a chainage based on the cell size. That is the chainage runs from cell centre to cell centre plus additional contributions from the first and the last cell. The MIKE 21 chainages are subsequently normalised so that they span the lateral links chainage.

- Depending on the method used the lateral structures will be set up according to the 2D cells or the river grid points. The chainage of the structures will be based on the chainages in the river.
- The chainage of the structures are normalised so that the span the same as the river chainage. The code uses the location based on these normalised chainages to locate which cells and h-points match up with which lateral structure.

### Flexible Mesh

MIKE FLOOD with a flexible mesh treats the lateral links in the following way

- The h-grid points within the linked river reach are identified.
- The linked MIKE 21 elements are given a chainages based on the segment chainage values. Each segment constitutes an internal lateral structure modelled as a weir.
- Depending on the method used the lateral structures will be set up according to the 2D topography or the river grid points. The chainage of the structures will be based on the chainages of the segments.

### Generating the ASCII file with the invert levels

To generate this ASCII file the following procedure should be followed:

- Set-up the MIKE Flood model
- Place an empty file named "MFLateral.txt" in the same folder as where the *sim11 file is located.
- Run MIKE Flood.
- The ASCII file is exported in the first time step of the run. Once the first time step of the simulation has been completed the file in step 2 will have been overridden with values describing the inverts of the lateral links.
- Open a new cross section file (*.xns11) and import the “MFLateral.txt” using File -> Import -> Import raw data.

The ASCII file has three entries for each lateral link given by:

  – M11 chainage, invert
  – M21 chainage, invert
  – Struck chainage, invert

The inverts of each of the links may now be investigated for possible inconsistencies.

## 3.5 Options for Urban links

There are a number of options available for an urban coupling each described below.

### 3.5.1 Type

There are four different types of links available.

- M21 to inlet: A link between the overland and a manhole in MOUSE. The urban ID is the node ID in this case.
- M21 to outlet: A link to an outlet in MOUSE. The urban ID is the node ID in this case.
- Weir to M21: A link between a MOUSE weir discharging out of the sewer/storm water system.
- Pump to M21: A link between a MOUSE pump discharging out of the sewer/storm water system and the MIKE 21 topography.

The links may be to multiple cells in the MIKE 21 rectangular grid or alternatively an area in the flexible mesh. If the latter is used at least 3 points must be supplied to constitute an area (polygon). If only one point is supplied in a given urban link then the discharge is introduced as a source/sink.

### 3.5.2 Inlet method

The exchange of water may be described through 3 different methods:

- Orifice equation: The flow between MOUSE and MIKE 21 is governed by a standard orifice equation.
- Weir equation: The flow is described through a weir equation.
- Exponential function: The flow is governed by a simple exponential function.

Depending on the calculation method used additional information is required.

### 3.5.3 Max flow

This parameters gives an upper limit on the discharge that can flow through the urban link. If the exchange calculated from the flow equation is above this value the discharge is reduced to this value.

### 3.5.4 Inlet area

The inlet area is only used when applying the orifice equation for describing the flow exchange between the urban and the 2D grid/mesh. The greater the cross sectional area the greater the conveyance capacity of the coupling. This parameter corresponds physically to the area of the manhole cover.

### 3.5.5 Crest width

The crest width is used when the flow exchange is described through a weir equation. The weir crest should be typically be the circumference of the manhole cover.

### 3.5.6 Scaling factor

Only applicable if the simple exponential expression is used to describe the flow exchange. The scaling factor has a linear effect on the discharge. Thus an increase in this value will generate a larger flow for a certain water level difference in the urban and the MIKE 21 model.

### 3.5.7 Exponent factor

Only applicable if the simple exponential expression is used to describe the flow exchange. An increase in the exponent factor has a strong impact on the discharge. An increase in this value will generate a larger flow for a certain water level difference in the urban and the MIKE 21 model.

# 4 RUNNING MIKE FLOOD- RECOMMENDED STEPS

Errors and inconsistencies in a model setup will occur. While every effort has been made to produce clear error messages, it can be difficult to keep track of all components in the model setup. To ensure that errors are minimised, we recommend following a clear, step by step procedure to develop and run MIKE FLOOD.

## 4.1 Define Model Layout

A MIKE FLOOD model is often a compromise between model resolution (grid/mesh size) and computational time required for a simulation. Note that computational time is mostly influenced by the total number of wet, computational points that occur over an entire simulation. This means that a flood simulation with a short duration, sharp peaked hydrograph will use much less computational effort compared to a long duration, flat peaked flood event. Consider this when deciding on grid resolution. Other things to consider include:

- The 1D model extent. Ensure that the working area in MIKE 11/MOUSE includes the full 2D extent.
- The 2D model extent
- Where model boundaries will be located - remember that often a MIKE FLOOD link is more flexible than applying a boundary condition directly in MIKE 21
- The alignment of the 2D grid - this may depend upon the alignment of main channels, flood plain features, etc.
- The type of links to be used.
- The geographical projection used must be identical for MIKE 11/MOUSE and MIKE 21.

## 4.2 Setup and Run 1D Models

MIKE FLOOD is a combination of MIKE 11/MOUSE and MIKE 21. Set up the individual models separately, then join them together using MIKE FLOOD.

It should be possible to completely define the 1D models that will be linked in MIKE FLOOD. This should be done to ensure that no errors

exist in the 1D models. While the results of the simulation will not be correct, they may provide an indication of potential problems.

## 4.3 Setup and Run MIKE 21 Model

As for the 1D setups, ensure no errors exist in the MIKE 21 definition files. Run the simulation and ensure that the results are reasonable. For flood plain applications this may include running a completely dry set-up with closed boundaries.

## 4.4 Setup MIKE FLOOD

The model layout should already be decided upon, and the individual models should already have the components ready for running the MIKE FLOOD model. This step is to create the MIKE FLOOD couple file and define the links to be applied.

## 4.5 Run MIKE FLOOD Simulation

Note that the standard links and the lateral links are explicit (Courant conditions cannot exceed 1). It is this initial simulation where the Courant conditions are likely to be encountered, and any stability problems relating to the links will occur. Do not be surprised if several adjustments of the links need to be made at this stage, or that the time step required is much shorter than you expected.

Check some of the tips available in this document (see Tips and Troubleshooting).

Once an initial MIKE FLOOD simulation has been completed, the modeller should have a good appreciation of the model layout and its various components, and be aware of the potential problems that may crop up in subsequent simulations and analyses.

# 5 PRE AND POST PROCESSING

It is envisaged that much of the pre- and post-processing of MIKE FLOOD will be done in a GIS. The GIS provides superior tools for the management and storage of large amounts of data, which is required for many flood plain applications. However, many GIS do not have specialised tools suitable for modelling (time series analysis, grid editing, surface interpolation etc.), so MIKE ZERO has its place in the modelling method. Standard spread sheets (EXCEL) are also useful for data management.

Links to external programs are available at present through MIKE ZERO. Linkage properties can be imported into MIKE FLOOD either through an external ASCII file (XYZ files from a GIS) or by cutting and pasting into the MIKE FLOOD interface.

The results from MIKE FLOOD (water levels, discharges, fluxes, AD components etc.) can be viewed using the Result Viewer, Plot Composer and Data Viewer (MIKE 21) and MIKE VIEW (MIKE 11, MOUSE, MIKE URBAN). Also, MIKE ZERO allows MIKE 21 result files to be exported to an ARC-GIS ASCII input file.

The recommended tool to use for MIKE 11/MIKE 21 rectangular grid couplings is the Result Viewer, which is activated from MIKE ZERO (File- New - Result Viewer). The viewer can present 1D, 2D and 3D results from different DHI Software models at the same time, including *.res11 result files from MIKE 11 and *.dfs2 results files from MIKE 21 rectangular grid:

- New files are added to the Result Viewer project by using Result Viewer - Projects - Add files to project and press the new “page” icon to the right. The “File Type” is a scroll-down menu, where the result file is chosen.
- The work area is defined under Result Viewer - Projects - Work Area.
- In order to display the results together, the two models need to be based on the same geo-reference. Thus, the MIKE 11 network must be described in the same UTM metric grid as the MIKE 21 bathymetry file.

- The type of result data to display (contours and/or vectors) is selected in Result Viewer - Projects - Active View Settings. On-line animation as well as production of videos can be done. Time series can be extracted by using the time series button at the upper tool bar (to the right). Use double click on the left mouse button to select a point graphically and display the time series in a separate window. Use Ctrl + Left click to select more points graphically, and display all the time series in a separate window by use Ctrl + Double Left mouse click.

For Urban links MIKE View may be used to display dfs2 result files superimposed on MOUSE results. Please refer to the MIKE View manual for how to add dfs2 files in MIKE View.

Additionally there are the option of displaying grid based results in Google Earth using the flooding plug-in. Though note that to use these tools the grid results must be geo-referenced (i.e. not NON-UTM).

## 5.1 Google Earth plug-in

To use this plug-in Google Earth must be installed (http://earth.google.com/). Once this has been installed the DHI plug-in may be installed from the installation DVD.

To visualize inundation in Google Earth the following procedure should be followed:

1 Start the Google Earth plug-in by selecting Start -> Programs -> DHI Software -> Google Earth Flooding

2 Within Google Earth go to the options menu which may be found under: Tools -> Options. Click on the preferences tab and deselect the field ‘Show web results in external browser’.

3 In the left overview window under places there is a menu item termed ‘new floodmap’. Within this menu item a ‘Load dfs2 file ...’ hyperlink is present select this.

4 Browse for the dfs2 to be used. Note that the dfs2 file must be geo-referenced otherwise the file cannot be placed correctly on the globe.

5 Click on the ‘Get statistics’ button. A dialog will appear asking whether an ActiveX component may be launched. Please select ‘yes’.

6 The next menu will prompt the user as to whether the images from the dfs2 file are to be generated. Please answer ‘yes’ unless the images have already been created previously (by having used the tool on this particular file before).

7 Another ActiveX window will prompt the user. Please select ‘yes’ to this query.

8 A final message box will appear once the images have been created and loaded.

9 Once the file has been loaded and the corresponding images (overlays) created the web viewer should look like figure Figure 5.1.

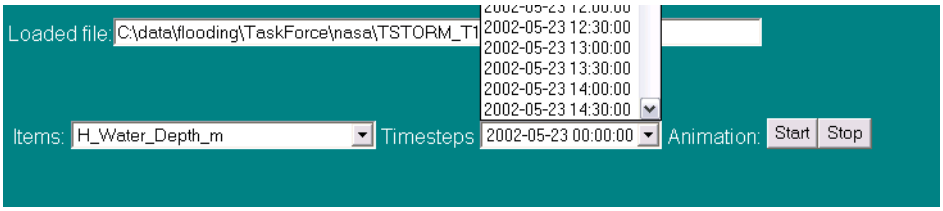



*Figure 5.1 The Google Earth plug-in for viewing 2D rectangular grid results as overlays.*

10 Various items may be displayed though note that the legend does not graduate the values. Thus if a cell is flooded it will be activated in the corresponding image.

11 To animate the inundation select a specific time step and click the ‘start button’.

# 6 TIPS AND TROUBLESHOOTING

## 6.1 General Considerations

- File Layout: MIKE FLOOD is designed so that all information relating to MIKE FLOOD is stored in the coupling file. The MIKE 11, MOUSE, MIKE URBAN and MIKE 21 simulation files are standard, which means that the models can be run separately.

### MIKE 11

- Initial Conditions: To obtain a stable MIKE FLOOD simulation, it is important that the hydraulic conditions are in dynamic equilibrium at the link point. This especially important at standard links and structure links. For these link types the initial water levels in the MIKE 11 and the MIKE 21 should be the same. Alternatively, hot-start files in the individual setup could be used.
- MIKE 11: The DELTA coefficient dampens high frequency oscillations from a MIKE11 simulation. The frequency of the dampened oscillations depends upon the time step and the value of DELTA. Note that the time step for a typical MIKE FLOOD application is relatively small, which means that increasing DELTA is unlikely to have a significant effect upon the accuracy of model predictions. Therefore, increasing the DELTA parameter is therefore a very useful feature for eliminating minor wobbles and potential instabilities from a simulation. See the MIKE 11 Scientific Documentation for a more detailed description.
- Additional Options: Additional options can be specified in the MIKE 21 parameter file. In the couple file, the entry M21_Run_Info contains four variables:
  - The first is obsolete but is left in for compatibility.
  - The second parameter indicates the level of debug information reported (0 for none and 1, 2 or 3 for debug output). If the parameter is 3 then only Courant number warnings are printed in the log file.
  - The third parameter is default 1 indicating that the same time step is used in MIKE 11 and MIKE 21. MIKE Flood my be run with a different time step in the two models. The default is that the time step is carried over from MIKE 21. Thus the time step specifications in MIKE 11 are over written when running MIKE Flood. If desired the time step in MIKE 11 may be chosen as a multiple of the time step in MIKE 21. The third parameter after the M21_Run_Info keyword specifies the time step multiplication factor used in MIKE 11.

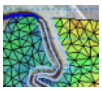
  - The last parameter is used to scale advection dispersion results (default 1.0). Incoming MIKE 11 AD concentrations are divided by this value in MIKE 21. The MIKE 21 AD solver treats any pollutant or constituent as a scalar and thus does not consider the unit of the pollutant. This parameter is used to ensure that the same unit is used in MIKE 11 and MIKE 21. MIKE 11 internally calculates concentrations in $g/m^3$.

- The option M21_struc_dirtol applies a tolerance to linkage directions for links to MIKE 11. This can be used to force flow directions in MIKE 21 to be aligned with the grid. That is if the flow direction is within the tolerance in degrees it will be aligned with the grid.

### MIKE 21 rectangular grid

- Wetting and Drying: Any link can be initially dry, or can dry at any time in the simulation. If a link is completely dry, flow will be added to the dry MIKE 21 cells until cell water depth is above the cutoff flooding depth. Then the cell will become an active wet point.
- Boundaries: MIKE FLOOD linkages in MIKE 21 rectangular grid do not necessarily need to be aligned with the MIKE 21 grid. This is different to the restrictions imposed on boundary locations in MIKE 21. Utilise this feature for any MIKE 21 simulation.
- Note that boundaries in MIKE 21 rectangular grid are not allowed to dry out. Therefore it is recommended for in land flood plain projects to close all open boundaries in the MIKE 21 bathymetry. Hereby all boundaries in the set up will be handled by the 1D models.
- MIKE 21: The default value for land in a MIKE 21 bathymetry is 10. If a flood plain model has bed elevations higher than this, ensure that the bathymetry file has this specified.
- MIKE 21: For applications with significant wetting and drying the Smagorinsky eddy viscosity formulation should not be used. This means that for the majority of MIKE FLOOD applications a constant eddy viscosity formulation should be applied. For overland flow conditions it is unlikely that eddy viscosity will have a major effect on model predictions (friction will dominate). However, for flow in and around structures, the value of eddy viscosity can have a significant effect upon predictions. Caution is advised in such cases.

### MIKE 21 flexible mesh



- The MIKE FLOOD run time will be impacted by the mesh size. Thus it is advantageous to spend some time initially in generating a sound mesh which represents the major features of the topography without resorting to very small elements.

- When using the flexible mesh the code will locate the nearest mesh element face and apply the discharge exchange along this face. Therefore it is beneficial to integrate the linkage lines into the mesh. The latter may be done using the additional feature for exporting the linkage lines.
- The flexible mesh couples along lines in the model. The discharge is distributed along these lines and it is therefore of outmost importance that these coupling lines are completely contained within the mesh. Ideally the lines should be integrated in the mesh.
- The flooding, wetting and drying values should be decreased from the default values. A reduction of a factor in the order of 50 is recommended.
- The flexible mesh version of MIKE FLOOD uses an adaptive time step for the overland flow (2D). Information is exchanged at every overall time step controlled by MIKE 21. The 1D models use the time step defined in the MIKE 21 set-up. Thus the time step should be selected based on considerations of the 1D models MOUSE and MIKE 11.

### MOUSE or MIKE URBAN

- It is important to look at weirs and pumps in the system and find out if they should be coupled to the MIKE 21 model in such a way that the water flows naturally. Flow from weirs in MOUSE is one directional, i.e. the flow only flows into the MIKE 21 model and not back into the MOUSE model. This can be fixed if needed by adding a small pipe and an outlet to the MOUSE model and couple in the outlet instead.
- MOUSE will automatically allow MIKE 21 to change the ground levels in manholes, if the change is within an acceptable limit. The limit may be set in the 'DHIapp.ini' file (MM21_ALLOWEDGROUNDLEVELDIFFERENCE). It is in general recommended to ensure that manhole levels correspond to the topography.
- It is important to consider the artificial basins on top of manholes in MOUSE i.e. the reservoir height above ground. The reservoir height is the distance from the manhole ground level to where the expansion for ponding starts. 25 cm below the man hole level is the default value, but when coupling MOUSE with MIKE FLOOD this should be increased to e.g. 100 m above. Make sure the FLOODLIMIT parameter does not conflict with the reservoir height.

## 6.2 Stability

- The MIKE 11, MOUSE, MIKE URBAN and MIKE 21 manuals contain information on stability in numerical modelling. The comments made are equally applicable for MIKE FLOOD.
- Most issues relating to stability in MIKE FLOOD occur in the links themselves and in the wetting and drying in MIKE 21. The numerical solution of both is explicit, and the dominant constraint is the time step.
- Another important factor relating to stability is wetting and drying. To some extent this can be a model design issue and adjustments can be made to improve stability. For example, make troublesome link points fully wet if possible, or reduce the time step / increase the MIKE 21 grid/mesh size (decreasing the Courant number can minimise the impact of other sources of instability). Including a depth dependence to the link, which will reduce the flow rate in shallow cells (relative to deeper cells within the link), may also help.
- The links Standard, Urban and Lateral are explicit. Meaning that time step considerations become very important. The numerical design of the links however means that the local Courant conditions inside the linked cells / h points cannot exceed 1. The local Courant number is defined as:

$$C_R = \frac{(v + \sqrt{gd})\Delta t}{\Delta x} \tag{6.1}$$

where

$v$ = velocity,

$g$ = gravity,

$d$ = water depth,

$\Delta t$ = time step and

$\Delta x$ = grid spacing.

**MIKE 11**

- See the description above in Section 6.1 (MIKE 11) pertaining to use of the DELTA coefficient in MIKE 11 to dampen potential instabilities. In most cases, increasing DELTA (to say 0.85) will not adversely affect model predictions.

- Set the momentum factor = 0.0 in links where momentum conservation is unlikely to be important.
- For lateral links, try to make the structure resolution the same as or finer than the MIKE 11 $\Delta x$ and the MIKE 21 grid size.
- If modelling a simple structure between adjacent MIKE 21 cells, use the implicit structure link. This link type is significantly more stable than a standard link.
- Stability in a link is improved if flow is continuous in one direction only through the link (for example, cascading flow over a weir). Try to utilize this when building the model by selecting link locations where backwater effects are less significant.
- Other adjustments, such as increasing friction and / or eddy viscosity, can be used to improve stability. However, such adjustments can compromise model performance.

## 6.3 Standard Links

- The end of branches in MIKE 11 that connect to MIKE 21 must have a water level boundary specified. This is a dummy boundary specification for initialisation purposes and will not affect the MIKE FLOOD simulation.
- Link points in MIKE21 can be dry initially, and can wet or dry during a simulation.
- MIKE 21 rectangular grid only: A predictor (extrapolation factor) is applied for obtaining proper time centring of the values that are exchanged between MIKE 11 and MIKE 21 rectangular grid. The predictor assumes that the flow between the last two cross-sections in MIKE 11 before the coupling is based on normal bed resistance flow (i.e. no structures). If there is a structure in the previous q-point before the coupling point, the extrapolation factor is set to 0. Note that this may affect stability of the link.
- MIKE FLOOD computes discharge from MIKE 11 and distributes it to the associated point(s) in MIKE 21. If the link in MIKE 21 consists of more points, the discharge is distributed uniformly to all points. If the depth distribution flag is used, flow is distributed according to water depth in each individual cell.
- The discharge from MIKE 11 influences the continuity equation as well as the momentum equation. The direction of the flow is derived from comparison of the orientation of the MIKE 21 grid and the direction of the MIKE 11 branch.

- MIKE FLOOD computes the water level from the link point/area in MIKE 21 and assigns it to the associated boundary point in MIKE 11. If the MIKE 21 link consists of more points, the average value from these points is transferred to MIKE 11. In general, more than one linked MIKE 21 grid point will tend to smooth and stabilise a coupling.

## 6.4 Lateral Links

- Lateral links can cause oscillations in the flow through the link when the difference in water levels between MIKE 11 and MIKE 21 is similar. To minimize such oscillations, use the depth tolerance factor. Also, consider using a friction coefficient in the links - it is considered physically correct in situations with vegetation on the river levees, and improves link stability. A value of 0.1 meter is recommended for the depth tolerance.
- When performing initial tests with MIKE 11 (with no MIKE FLOOD links), do you get the error message “Error no 25 : At the h-point: .... the water depth greater than 4 times max. depth.”? This can occur if the bank markers in the cross-sections (which will be laterally linked to MIKE 21) are low. To avoid this message, the MIKE11.INI file HD entry WL_EXCEEDANCE_FACTOR should be set to a higher value (say 50). Also use a local MIKE11.INI file by copying the file from the installation to the directory where the *.sim11 file is located. Hereby the settings in the MIKE11.INI file only affects the present set up.
- A high resolution of MIKE 11 grid points improves model stability.
- Use the CELLTOCELL method for lateral flows.
- The WEIR1 and WEIR2H types are linked to the MIKE 11 structure routines. They include drowned conditions and simulate lateral flows accurately. The FORMLOSS method is straightforward. If these methods are not sufficiently detailed then an external QHTABLE type is available. H is considered to be water level (either in MIKE11 or MIKE21). Otherwise, QDTABLE uses (water level - structure depth). Also, if a CELLTOCELL method is applied then Q is flow per unit width.

- Bed friction can be included in the weir calculation (see the Scientific Background). While this is normally uncommon for in-channel structures, river bank overflow can often occur across reasonable distance (the levee width) and through thick vegetation. Rather than estimating a new weir coefficient to account for this, specification of a friction term may be a desirable alternative. The length of the link used in this calculation is determined from the MIKE 21 cell size for the rectangular grid version. For the flexible mesh version a weighted distance from the river grid points and the individual linkage segments is used for describing the length.
- Lateral links can oscillate when the difference in water levels between MIKE 11 and MIKE 21 is similar. To avoid this, use the Depth Tolerance factor. A value of 0.1 meter is recommended.
- Using the highest (HGH) structure source type is usually the most convenient method. This picks the highest resolution of points (MIKE 21 cells or MIKE 11 h points), then assigns bed levels using the highest values from the MIKE 21 cells and MIKE 11 points. If available, external input from a GIS could be used to extract more detailed bank line information.
- To view the lateral flows in the MIKE 11 results file, tick the “Lateral Links” option in the Additional Output menu of the HD Parameter File (.HD11).

## 6.5 Structure Links

- The structure links are implicit. This means that a simulation that uses these links will be more stable than the explicit links and simulations can be performed using longer time steps.
- In the structure links MIKE 11 lags one time step behind MIKE 21. Thus, the displayed value of flow in the q point of the MIKE 11 branch may not necessarily be the flow through the MIKE 21 cell. It is recommended that for structure links the MIKE 21 results be interrogated rather than the MIKE 11 results.
- The direction of the flow is derived from comparison of the orientation of the MIKE 21 grid and the direction of the MIKE 11 branch. A projection is made of the flow equation onto the grid cell faces.

- The MIKE 21 cells that define the inlet and outlet of the structure link must be adjacent to each other. Thus if the inlet cell is $(J_1,K_1)$ then the outlet cell must satisfy at least one of the equations (6.2). However, more than one MIKE 21 cell can be specified and a list of cells can be in any direction or alignment.

$$\begin{aligned} K_2 &= K_1 - 1 \\ K_2 &= K_1 + 1 \\ J_2 &= J_1 - 1 \\ J_2 &= J_1 + 1 \end{aligned} \tag{6.2}$$

- The river branch that defines the structure link can only be a 3 point branch (one h point at the inlet, one h point at the outlet, and one q point connecting them). The q point can have as many parallel structures as are needed, or can have no structures (it can simply be a cross-section).
- There is an option to add or replace momentum terms. If the momentum terms are replaced, the flow conditions calculated in MIKE 11 override flow conditions in the MIKE 21 cell. If the momentum terms are added, the flow conditions calculated in MIKE 11 are added to the flow conditions in the MIKE 21 cell.

## 6.6 Zero Flow Links

- A single link can be used to specify all XFLOW=0 cells in a MIKE 21 grid. The same applies for the YFLOW=0 cells.
- With regard to activation depth, the idea is that for most flooding conditions there will be left bank flood plain flow, in-bank channel flow and right bank flood plain flow. The interactions between these three will be governed by the MIKE FLOOD links. However, water depths could increase until the interactions between the separate flow paths are no longer relevant. At this stage, a MIKE 21 simulation without the MIKE FLOOD links would be more accurate. By using the activation depth to switch on 2D flows across a river channel this could be done.

## 6.7 Urban links

- It is possible to couple to multiple cells if using a rectangular grid. For the flexible mesh it is possible to couple to an area. In general using multiple cells or an area as opposed to coupling to only one point will enhance stability.

# 7 SCIENTIFIC BACKGROUND

The scientific backgrounds of MIKE 11, MOUSE and MIKE 21 are also applicable for MIKE FLOOD.

## 7.1 Hydrodynamics - Standard Links

Standard links are treated slightly differently depending on whether a flexible mesh or a rectangular grid is used.

### Rectangular grid

Discharge is extracted from the MIKE 11 boundary (the first $Q$-point), and imposed in MIKE 21 in a similar way as a MIKE 21 source discharge. The discharge is centred at time step $n$+1/2. The discharge from MIKE 11 has an impact on the continuity equation as well as the momentum equation in MIKE 21 as with a normal source discharge, (see MIKE 21 scientific documentation).

MIKE 11 requires a water level boundary from MIKE 21 at time step $n$+1 in order to step from time step $n$ to $n$+1. Therefore, MIKE 21 will always be one time step ahead of MIKE 11. Thus, in order to provide a discharge to MIKE 21 at time step $n$+1/2, a predictor may be applied in MIKE 11 to estimate the discharge $Q^{n+1/2}$, given the computed discharges $Q^n$ and water levels $H^n$ at time step $n$:

$$\frac{\partial Q^{n+\frac{1}{2}}}{\partial t} = -\left( gA\frac{\partial H^n}{\partial x} + \frac{Q^n \cdot \left|Q^n\right|}{A \cdot C^2 \cdot R} \right) \tag{7.1}$$

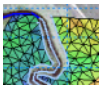
where

$t$ = the time,
$x$ = the length,
$A$ = the cross-sectional area,
$C$ = the Chezy resistance number, and
$R$ = the hydraulic radius.

The gradient in water level is evaluated at the last $Q$ point in MIKE 11. The calculated time derivative of discharge is transferred to MIKE 21 together with the discharge at time n in order to predict the discharge at a later time step ($n$+1/2).

The predictor assumes that the convective acceleration terms in the last grid point in MIKE 11 are negligible. Furthermore, it assumes that "normal" bed resistance represented by a Chezy (or Manning number) controls the flow. If a structure is present in the last *Q* grid point in MIKE 11 a link to MIKE 21 the predictor is not used.

### Flexible mesh



For the flexible mesh the standard link is designed is such a way that the linkage line is mapped onto one or more element faces. Thus from MIKE 21's point of view the link functions as a boundary condition. In return MIKE 21 transfers an average water level across the coupled element faces which is then subsequently used in MIKE 11. It is required that the whole of the coupling line is within the mesh to ensure that total discharge is transferred from the river model to the overland mesh model.

The predictor is not used for the flexible mesh solution. I

## 7.2 Hydrodynamics - Lateral Links

For lateral links, flow from the river model goes via a lateral boundary, which is then applied into MIKE 21. The lateral link varies from the standard source / sinks in the following ways:

1 Flow through the link is dependent upon a structure equation and water levels in MIKE 11 and MIKE 21.

2 Flow through the link is distributed into several MIKE 11 *h* points and several MIKE 21 cells/elements.

3 The lateral links do not guarantee momentum conservation.

The latter point is not surprising since the 1D-model per definition does not consider cross channel momentum.

A structure is required to calculate the flow between MIKE 11 and MIKE 21. This structure is typically a weir that represents over topping of a river bank or levee. The geometry of the structure can be determined from cross section bank markers, MIKE 21 topographical levels, a combination of the highest of each, or from an external file.

### Rectangular Grid

With a CELLTOCELL method, the structure geometry is subdivided into a series of internal structures. Each internal structure has a bed level and a width determined from the resolution of points defined along the structure.

Consider the schematic diagram in Figure 7.1 of a structure defined from MIKE 11 *h* points:

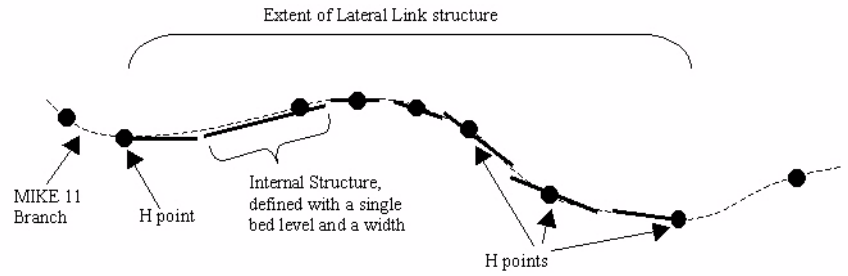



*Figure 7.1 Lateral Link, Definition of Internal Structures*

The internal structures are defined so that all of the information available in the structure geometry is utilised.

During computation, each internal structure is assigned a water level from the river and from the overland solver. These values are found by interpolating levels at existing calculation points onto the internal structures. Consider the schematic diagram in Figure 7.2 of an externally defined structure, where the internal structure locations differ from the MIKE 21 cell locations and the MIKE 11 h point locations. As shown, water levels are interpolated from the MIKE 21 cells and the MIKE 11 *h* points to the specific internal structure locations.

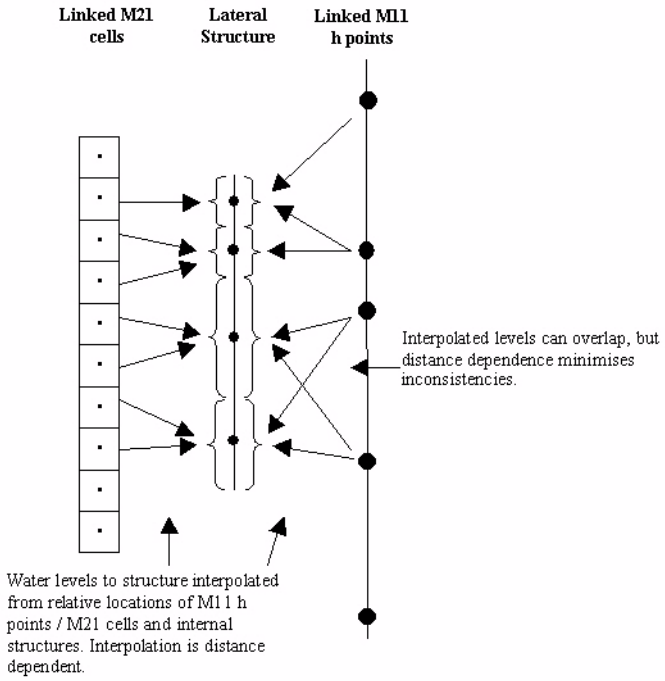

Linked M21 cells
Lateral Structure
Linked M11 h points
Interpolated levels can overlap, but distance dependence minimises inconsistencies.
Water levels to structure interpolated from relative locations of M11 h points / M21 cells and internal structures. Interpolation is distance dependent.

*Figure 7.2 Lateral Link, Interpolation of Water Levels*

Using the calculated width and bed level and interpolated water levels, the flow across each internal structure is calculated using a standard structure equation. These structure equations are the same equations used in MIKE 11. The flow from each internal structure is then distributed to / from the MIKE 11 h points and MIKE 21 cells. This is done by determining the range of influence that each internal structure has upon each linked MIKE 11 h point and MIKE 21 cell. As shown in Figure 7.3, if MIKE 11 *h* points lie within the range of influence of a given internal structure, flow is distributed across those points according to water depths in each point. If no MIKE 11 h points lie within the range of influence, flow is distributed to the nearest upstream and downstream points using a distance dependent interpolation. The same applies for MIKE 21 cells.

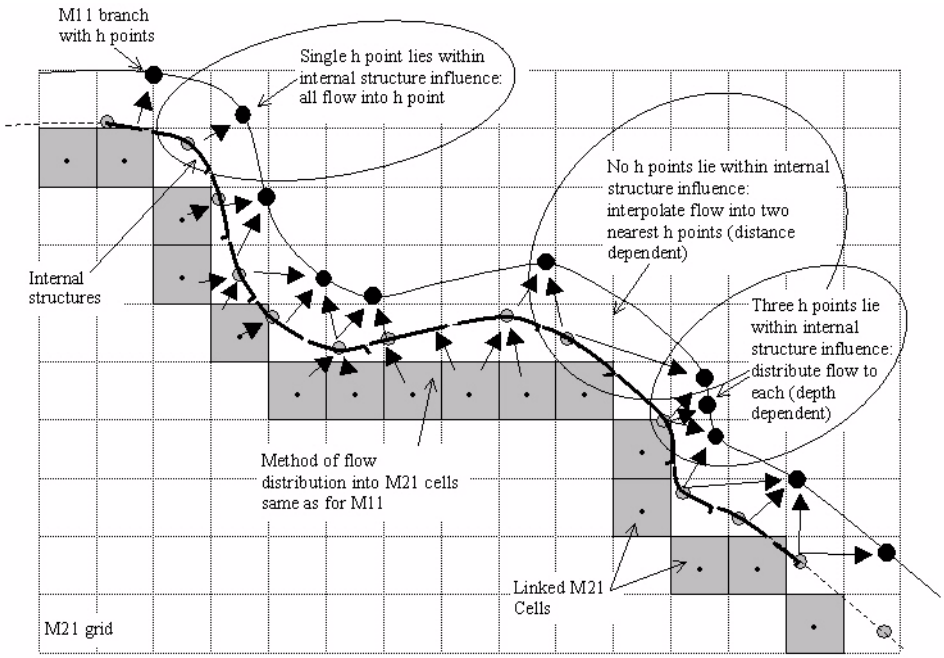



*Figure 7.3 Lateral Link, Interpolation of Flows*

This approach allows a high level of flexibility when designing the lateral link. However, it is likely that a similar distribution of MIKE 11 *h* points, MIKE 21 cells and internal structures will produce the most accurate solution.

### 7.2.1 Automated cell selection

The automated cell selection tool may be used for the centre line or the left or the right levee line. The cell/element selection only varies in the way the line is defined. The centre line is defined through the digitised points in the MIKE 11 set-up. The construction of the levee lines follows through a number of fully automated steps (see Figure 7.4):

1 The cross sections located within the user selected reach are placed according to either the geo-referenced coordinates or the chainage. The latter only if the coordinates are not present or applied.

2 If the cross sections are placed according to the chainage (not geo referenced) then the distance from the centre line depends on the location of markers 1,2 and 3. If these markers are not present they are determined from the raw data.

3 If cross sections are not present at the end points of the user defined reach then extrapolated widths are determined from the existing cross sections.

4 At all digitised points without a cross section the width is interpolated from the existing cross sections.

5 The interpolated widths are placed so that they bisect the angle of the two adjoining line segments.

6 The levee lines are thus made up by joining the respective left or right end points of the combined interpolated widths and cross sections.

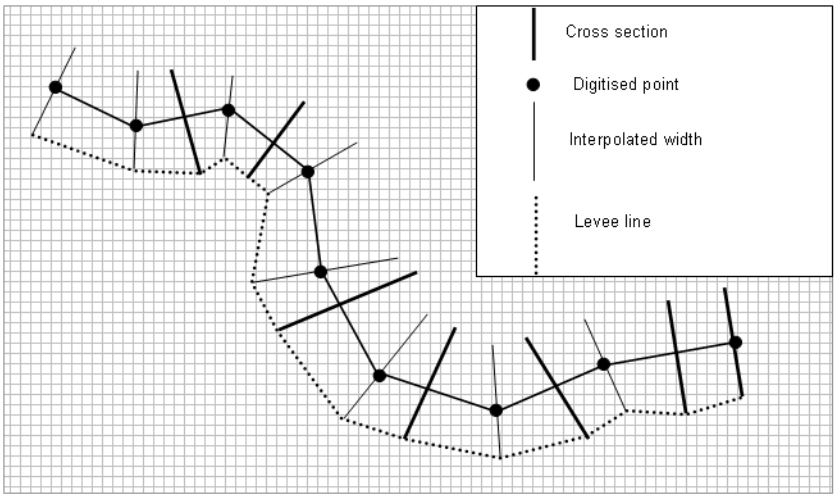



*Figure 7.4 Definition of levee line used for lateral linkage.*

### 7.2.2 Definition of lateral linkage lines

The linkage tool in MIKE Flood can trace cells intersected by a line. The line being one of three types:

- Center line
- Left levee line
- Right levee line

The only difference between the three is the construction of the line. The center line is simply the digitised river from the MIKE 11 set-up. The left and the right levee lines are constructed based on the cross sectional widths.

When using the flexible mesh the individual elements to be coupled are identified at run time. Thus the linkage is independent of the element size. The linkage in this case is made up of the coordinates of the end points of the line segments making up the linkage line. At run time the linkage line is mapped unto the element faces.

## 7.3 Hydrodynamics - Structure Links

The structure link takes the implicit terms describing momentum through a 3 point MIKE 11 branch and uses them to replace or modify the implicit terms describing momentum across the face of a MIKE 21 cell. In this way, the flow properties from one MIKE 21 cell to another are modified to represent a structure. Consider the following diagram:

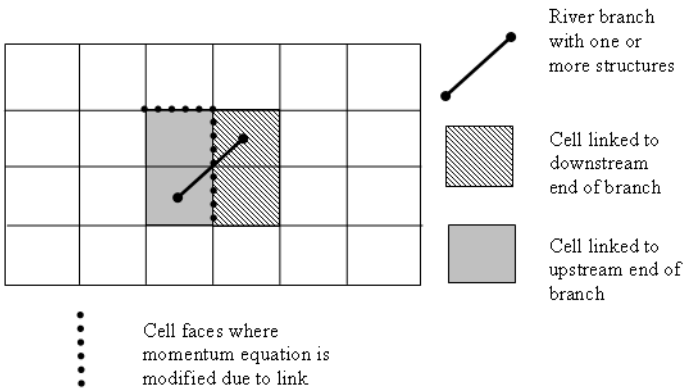

River branch with one or more structures
Cell linked to downstream end of branch
Cell linked to upstream end of branch
Cell faces where momentum equation is modified due to link

*Figure 7.5 Structure Link Diagram*

The momentum equation from the MIKE 11 q point replaces the x-momentum and y-momentum equation of the upstream MIKE 21 cell. This is the only thing that is modified within MIKE 21. Note that the cells at the downstream end of the branch are only used to extract a water level to be used when evaluating the momentum equation.

When the MIKE 11 momentum equation replaces the MIKE 21 momentum equation, the implicit terms for the momentum equation within the MIKE 21 cell are replaced. Adjustments are made for link direction ($\theta$)

and conversion from discharge ($Q$) to flux ($q = Q/\Delta$, $\Delta$ = 2D cell size). For the momentum equation in the x direction:

$$a_{M21} h_{j+1}^{n+1} + b_{M21} q_{j+1}^{n+1} + c_{M21} h_{j-1}^{n+1} = d_{M21} \tag{7.2}$$

$$a_{M21} = \frac{a_{M21} \cos\theta}{\Delta} \tag{7.3}$$

$$b_{M21} = b_{M11} \tag{7.4}$$

$$c_{M21} = \frac{c_{M21} \cos\theta}{\Delta} \tag{7.5}$$

$$d_{M21} = \frac{d_{M21} \cos\theta}{\Delta} \tag{7.6}$$

If the terms are added (for example if the structure link represents a structure flowing under the existing MIKE 21 topography), further adjustments are made to ensure consistency between the MIKE 11 and MIKE 21 terms. Again for the x direction:

$$a_{M21} h_{j+1}^{n+1} + b_{M21} q_{j+1}^{n+1} + c_{M21} h_{j-1}^{n+1} = d_{M21} \tag{7.7}$$

$$a_{M21}^{*} = a_{M21} + \frac{a_{M11} b_{M21} \cos\theta}{b_{M11} \Delta} \tag{7.8}$$

$$b_{M21} = b_{M11} \tag{7.9}$$

$$c_{M21}^{*} = c_{M21} + \frac{c_{M11} b_{M21} \cos\theta}{b_{M11} \Delta} \tag{7.10}$$

$$d_{M21}^{*} = d_{M21} + \frac{d_{M11} b_{M21} \cos\theta}{b_{M11} \Delta} \tag{7.11}$$

The same adjustments apply for the y direction momentum equation, except a sine direction adjustment is made rather than a cosine adjustment.

Note that the implicit terms from MIKE 11 used are from the MIKE 11 solution at the previous time step. In most applications, where flow condi-

tions vary quite slowly relative to the time step, this is not a problem. It may become a problem if rapid (and relevant) changes do occur over a time step. Also, the displayed value of flow in the *q* point of the MIKE 11 branch may not necessarily be the flow through the MIKE 21 cell. It is recommended that the MIKE 21 results are interrogated in this case rather than the MIKE 11 results.

### 7.3.1 Hydrodynamics - Exponential smoothing factor

The exponential smoothing factor may be used for links which are misbehaving causing oscillations. The exponential smoothing factor works by applying a weight to the transferred water level from MIKE 21 to MIKE 11. The expression reads

$$H_{M11}(n) = (1-\alpha)H_{M11}(n-1) + \alpha H_{M21}(n) \tag{7.12}$$

where $\alpha$ is the smoothing factor, $H_{M11}$ is the MIKE 11 water level, $H_{M21}$ the MIKE 21 water level and $n$ is the time step. By applying this expression $n$ times the water level may be given as

$$H_{M11}(n) = (1-\alpha)^n H_{M11}(0) + \alpha \sum_{i=0}^{n} (1-\alpha)^i H_{M21}(n-i) \tag{7.13}$$

Using the above expression a criteria for selection of the smoothing factor may be obtained. Assuming that the water level in MIKE 21 in constant then the number of time steps $n$ it will take the MIKE 11 water level to be within a fraction $f$ of the MIKE 21 water level is given by

$$n = \frac{\log f}{\log(1-\alpha)} \tag{7.14}$$

Thus the smoothing factor should be chosen in relation to the time scale at which the dynamics change in the model.

## 7.4 Hydrodynamics - Zero Flow Links

If the link type is a XFLOW = 0 link, the x direction momentum across the right face of the MIKE 21 cell is set so that $q = 0$. This is done by modifying the implicit terms:

$$a_{M21} h_{j+1}^{n+1} + b_{M21} q_{j+1}^{n+1} + c_{M21} h_{j-1}^{n+1} = d_{M21} \tag{7.15}$$

$$a_{M21} = c_{M21} = d_{M21} = 0 \tag{7.16}$$

$$b_{M21} = 1 \tag{7.17}$$

Similarly, if a YFLOW = 0 link, the y direction momentum across the top face of the MIKE 21 cell is set to $q = 0$.

## 7.5 Hydrodynamics - Urban links

The exchange of water ($Q_{UM21}$) at the inlet can be computed in three different ways:

- Orifice equation
- Weir equation
- Exponential function

The orifice calculation is given by:

$$Q_{UM21} = sign(H_U - H_{M21}) CMin(A_m, A_I) \sqrt{2g|H_U - H_{M21}|} \tag{7.18}$$

for $|Q_{UM21}| < Q_{max}$ , where

$Q_{UM21}$:Flow from sewer to MIKE 21 grid point.

$H_U$ Water level in sewer system.

$H_{M21}$: Water level on the ground.

$A_m$: Cross-sectional area of manhole.

$A_I$: Cross-sectional area of inlet.

C The weir coefficient.

The weir equation depends on whether there is flooding on the surface or not. If the surface is not flooded at the time, then it is calculated as a free flowing weir:

$$Q_{UM21} = (H_U - H_{M21}) W_{crest} \sqrt{2g|H_U - H_{M21}|} \quad (7.19)$$

for $|Q_{UM21}| < Q_{max}$ , where $W_{crest}$ is crest width to be used in the equation (.

If the surface is flooded then the weir is calculated as a submerged weir:

$$Q_{UM21} = (H_U - H_{M21}) W_{crest} \sqrt{2g|H_U - H_{M21}|} \left( \frac{H_U - H_{ground}}{H_U - H_{M21}} \right) \quad (7.20)$$

The last function for computing the flow between MOUSE and MIKE 21 is given by:

$$Q_{UM21} = S(H_U - H_{M21})^{Exp} \quad (7.21)$$

for $|Q_{UM21}| < Q_{max}$ , where

S : Simple scaling factor

Exp : Exponent

Note that eq. (7.21) the values of H are given in meters and the discharge is given in $m^3/s$.

There is an option to suppress oscillations by use of the QdH factor. The value corresponds to the water level difference at which the suppression is applied. The suppression is designed for cases where the pressure level in the sewer system is close to the water level in MIKE 21 and may be applied individually at each urban coupling. If a value of 0.0 is given then no suppression is applied.

## 7.6 Advection-Dispersion

Concentrations of AD components are transferred explicitly between MIKE 11 and MIKE 21 depending on the direction of the flow. For standard links with flow from MIKE 11 to MIKE 21, the concentration of the AD-component is imposed as with a standard MIKE 21 source, i.e. as a flux of mass into the MIKE 21points:

$$\Delta\left(\frac{\partial V \cdot C_{M21}^{n+½}}{\partial t}\right) = Q^{n+½} \cdot C_{M11}^{n} \tag{7.22}$$

When flow is going from MIKE 21 to MIKE 11, the modification to the AD-equation in MIKE 21 is:

$$\Delta\left(\frac{\partial V \cdot C_{M21}^{n+½}}{\partial t}\right) = Q^{n+½} \cdot C_{M21}^{n} \tag{7.23}$$

The corresponding boundary condition in MIKE 11 can be either a transport boundary or a concentration boundary as usual. Furthermore, a mixing coefficient can be defined as normal.

For lateral links, the mass of the AD component being transferred is calculated from the lateral discharge and the concentration in MIKE 11 or MIKE 21 (depending upon flow direction). This is then applied as a source or sink term in the branches and cells. The source term into MIKE 21 is as for the standard links. For MIKE 11, the one dimensional advection dispersion equation is:

$$\frac{\partial AC}{\partial t} + \frac{\partial QC}{\partial x} - \frac{\partial}{\partial x}\left(AD\frac{\partial C}{\partial x}\right) = -AKC + C_2 q \tag{7.24}$$

where $C$ is concentration, $D$ dispersion coefficient, $A$ cross-sectional area, $K$ linear decay, $C_2$ the source/sink concentration and $q$ lateral inflow per river length.

For zero flow links, no advection will occur across the link due to the zero flow specification, and dispersion is turned off.

## 7.7 Flow Distribution by Depth

Flow is distributed according to the Chezy equation for resistance:

$$Q = AC\sqrt{RS} \tag{7.25}$$

where:

$Q$ = Flow;
$A$ = Area (= width · depth = $w \cdot h$);
$C$ = Chezy coefficient;

$R$ = Hydraulic radius (approx. = depth = $h$); and
$S$ = slope.

Rearranging this equation gives:

$$Q = whCh^{0.5}S^{0.5} = h^{1.5}wCS^{0.5} \tag{7.26}$$

Thus, proportionality can be derived between flow and water depth ($h$):

$$Q \sim h^{1.5} \tag{7.27}$$

Flow is then distributed across a number ($n$) of MIKE 21 cells. For each cell (count $i = 1...n$), the distributed flow $Q_i$ is calculated from the total flow $Q_{TOT}$:

$$Q_i = Q_{TOT}\frac{h_i^{1.5}}{\sum_{i=1}^{n} h_i^{1.5}} \tag{7.28}$$

## 7.8 Inclusion of Friction Term in Weir Formulae 1 and 2 (Honma)

The equation for the Weir Formula 1 is:

$$Q = wCh_1^k\left[1-\left(\frac{h_2}{h_1}\right)^k\right]^{0.385} \tag{7.29}$$

where $w$ = width, $C$ = weir coefficient (1.838 $m^{1/2}/s$), $k$ = exponential coefficient (1.5), $h_1$ = depth of water above weir level upstream ($H_{us}$ - $H_w$) and $h_2$ = depth of water above weir level downstream ($H_{ds}$ - $H_w$). This equation is actually a free overflow term ($wCh^k$) combined with a scaling term for submergence ($[...]^{0.385}$) that approaches 0 as $h_1$ approaches $h_2$. The equation for the Weir Formula 2 (Honma) is:

$$\begin{aligned} Q &= wCh_1\sqrt{h_1} && \text{for } \frac{h_2}{h_1} \le 2/3: \\ Q &= w\frac{3}{2}\sqrt{3}Ch_2\sqrt{h_1-h_2} && \text{for } \frac{h_2}{h_1} > 2/3: \end{aligned} \tag{7.30}$$

The first equation is free overflow (identical to Formula 1 with free overflow), while the second is for submerged conditions.

Both equations are derived from the equation for form loss across a structure, where

$$\Delta h = \zeta \frac{v^2}{2g} \tag{7.31}$$

If a friction loss is added this becomes:

$$\Delta h = (\zeta + F) \frac{v^2}{2g} \tag{7.32}$$

where:

$$F = \zeta_f \frac{2gLn^2}{h_1^{4/3}} \tag{7.33}$$

$\zeta_f$ = Friction coefficient;
$L$ = length of structure; and
$n$ = Manning's number.

Expanding:

$$Q = w \sqrt{\frac{2g}{(\zeta + F)}} h_1 \sqrt{\Delta h} \tag{7.34}$$

This equation is similar in form to Weir Formulae 1 and 2 for free overflow, except that the weir coefficient is replaced:

$$C = \sqrt{\frac{2g}{\zeta + F}} \tag{7.35}$$

Assuming that the entrance ζ exit losses (are the same, a new weir coefficient $C_f$ can be derived from the original coefficient $C$ and the additional friction:

$$C = \sqrt{\frac{2g}{\zeta}}; \zeta = \frac{2g}{C^2} \tag{7.36}$$

$$C_f = \sqrt{\frac{2g}{\zeta + F}} = \sqrt{\frac{2g}{2g/C^2 + F}} \tag{7.37}$$

So, the existing equations for weir flow calculations can be used, except that the weir coefficient is modified according to:

$$C_f = \sqrt{\frac{2g}{2g/C^2 + \zeta_f \frac{2gLn^2}{h_1^{4/3}}}} \tag{7.38}$$

This equation is applied to the weir calculations in the lateral link specifications.

# 8 EXAMPLES

The examples presented below are designed to test the operation of the features of MIKE FLOOD and to demonstrate the use of these features. Most are available with the DHI software in the “Examples” folder. Otherwise, check www.dhisoftware.com, where the input files can be downloaded.

Various MIKE ZERO tools can be used to view the results, including the Result Viewer, MIKE VIEW (not in MIKE ZERO), Plot Composer, and the time series, profile series and grid series editors.

A brief outline of the examples is provided:

- Standing Wave: examines momentum transfer through standard links
- Lateral Link 1: investigates lateral link flow over a bank of varying bed levels and includes an AD component
- Lateral Link 1: investigates lateral link flow and compares results to a standard MIKE 11 weir
- Flow Direction: examines flow directions through various links
- Flood plain Flow: examines the transition from in-bank to flood plain flow in a simplified setup
- Floodplain Demonstration: demonstration of a real flood plain application. The example is available both for the rectangular case as well as the flexible mesh version.

## 8.1 Standing Wave

Consider an 8 km long basin closed at both ends:

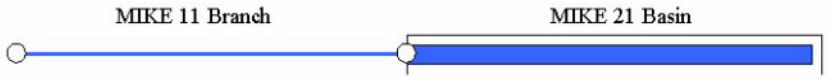



*Figure 8.1 Standing Wave Test Layout*

The width of the basin is 100 m and the mean water depth is 2.0 m. The bed resistance is C = 50 m1/2/s. An initial disturbance of the water surface is imposed corresponding to a sinusoidal variation of range 0.10 m.

The basin is described using MIKE FLOOD. 4 km is described in MIKE 11, and 4 km is described in MIKE 21. In both models, the longitudinal grid spacing is 100 m. MIKE FLOOD simulates the transfer of mass as well as momentum between the 1D MIKE 11 model and the 2D MIKE 21 model. The water level at different times after start of the simulation is depicted below.

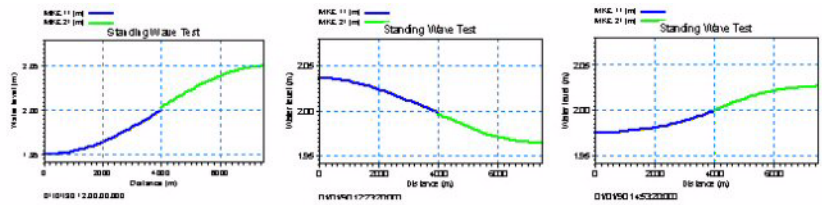



*Figure 8.2 Standing Wave Test Results - Water Level Profiles*

The files required to setup and run this example are available. These files take this example further than presented here, with tests using:

- the standard link type;
- a 10 cell / 1000 m wide setup of the same test case;
- a MIKE 11 model of the entire test (no MIKE FLOOD link); and
- a MIKE 21 model of the entire test (no MIKE FLOOD link).

Thus, four separate tests are included in this single MIKE FLOOD setup. The results are shown as water level profiles at various time steps:

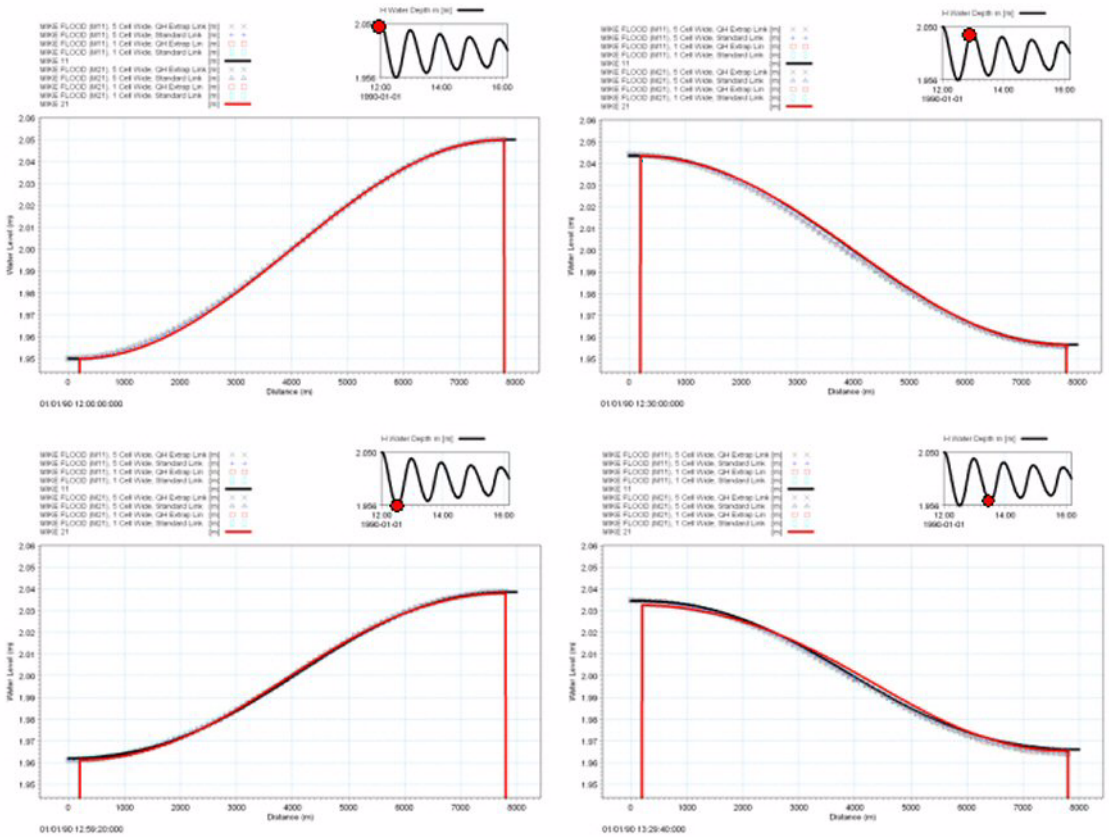


*Figure 8.3 Standing Wave Test Results - Water Level Profiles (2)*

While it is difficult to examine the individual curves, the plots shown above demonstrate that the various link types are performing satisfactorily. See the examples provided for further interrogation.

## 8.2 Lateral Link 1

This is a test to assess the performance of the lateral links and to illustrate their implementation. The test represents an inflow channel with over topping onto a broad flat basin (or flood plain), as shown:

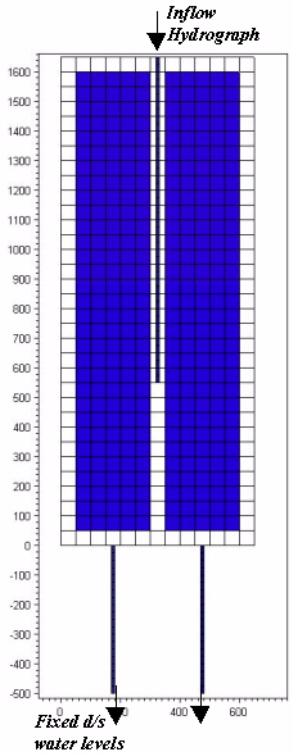



*Figure 8.4 Lateral Link Test 1 Layout*

An inflow hydrograph discharges into the upstream MIKE 11 river branch. Flow spills over the banks of the river channel and into the MIKE 21 basins. The left and right basins are separated by land. Two downstream MIKE 11 branches are connected to the end of the left and right basins. Water level boundary conditions are applied to the downstream branches. A closed boundary is applied to the downstream end of the upstream river branch.

The MIKE 11 network uses a 50 m spacing between h points, and the MIKE 21 grid has a spacing of 50 m. A simulation time step of 5 s is used.

The links at the downstream end of the MIKE 21 basin are standard links. The main interest in this test however is the lateral links. The left bank of the upstream branch (chainage 100 m to 1100 m) is connected to the MIKE 21 cells in the right basin (7, 31 to 7, 11). The right bank is connected to the left basin (5, 31 to 5, 11).

The left and right bank markers of the branch are defined by a sinusoidal curve as shown:

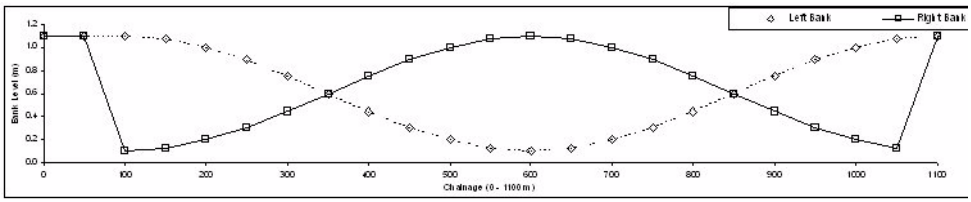



*Figure 8.5 Lateral Link Test 1, Left and Right Bank Levels*

Lateral flow spilling out of the river channel into the basin will be distributed across the length of the branch, depending upon the bank levels, the water level profile along the branch, and the flow distribution will vary between the left and right sides of the river.

The MIKE FLOOD couple file is “mf.couple”. Run this simulation, then inspect results using the Result Viewer in MIKE ZERO. Contours of water depth and vectors of velocity at two instances in the simulation are shown below:

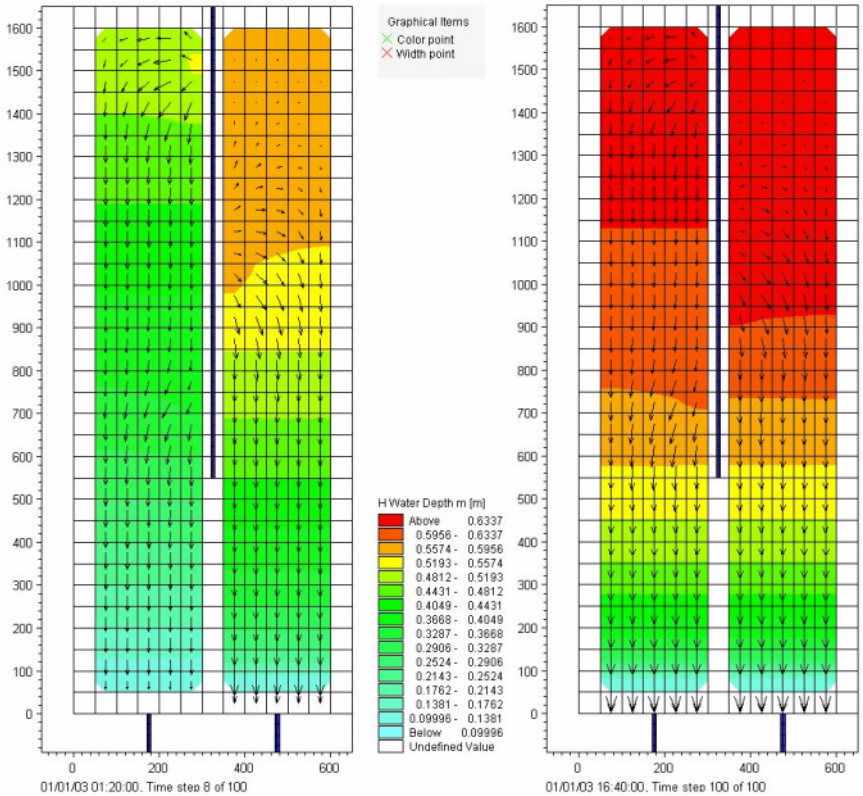



*Figure 8.6 Lateral Link Test 1 Results -Water Depth and Velocity*

There is a distinct difference in flow patterns between the left and right basins. Using MIKE VIEW, look at the longitudinal profile of the upstream branch:

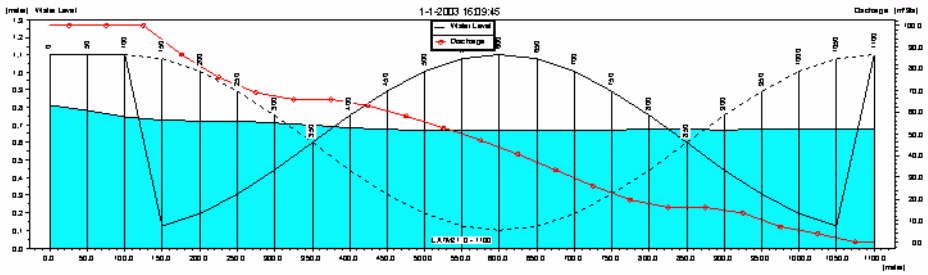


*Figure 8.7 Lateral Link Test 1 Results -Water Level and Flow Profile*

Similarly, the lateral discharges can also be presented (tick the "Lateral Inflows" button in the Additional Output Menu in HD Parameters):

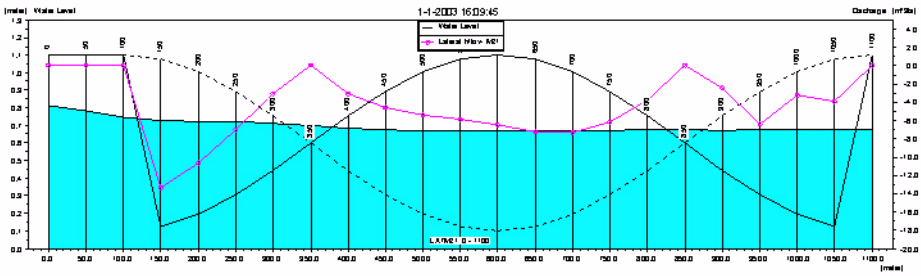


*Figure 8.8 Lateral Link Test 1 Results - Lateral Flow Profile*

Last (but not least), a check of the mass in the system can be made by comparing the total discharge into the model (the upstream inflow from the upstream branch) with the discharge out of the model (from the downstream branches):

As shown, 100 m3/s enters from upstream. The flows are distributed so that 47.76 $m^3/s$ flows through the left branch and 52.24 $m^3/s$ through the right.

*Figure 8.9 Lateral Link Test 1 Results -Time Series of Discharge*

For comparison, the same setup has been done using MIKE 11. For the MIKE 11 setup, the left and right basins are represented using branches. Flow from the upstream branch to the basins occurs through two additional branches with cross-sections representing the bank levels. The MIKE 11 test has been combined with the original MIKE FLOOD application (see mf2.couple):

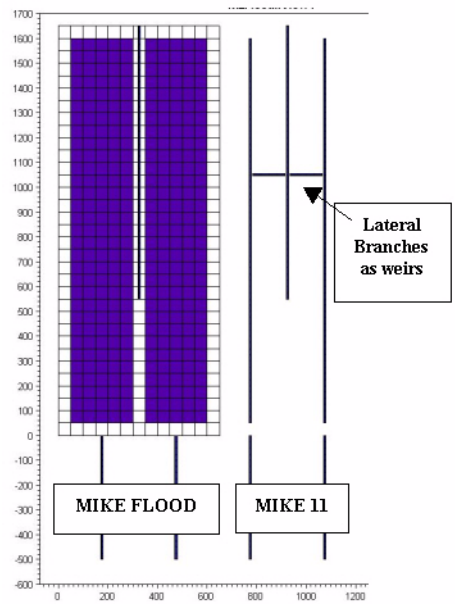



*Figure 8.10 Lateral Link Test 1 Layout (2)*

The MIKE 11 test has two branches representing lateral flow aligned equally at the centre of the upstream branch. Comparison of discharges from the downstream branches for the MIKE FLOOD and MIKE 11 tests are presented below:

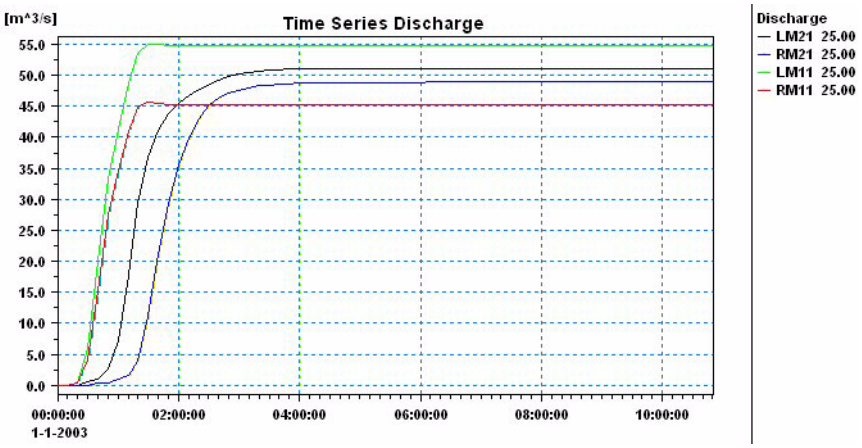



*Figure 8.11 Lateral Link Test 1 Results - Time Series of Discharge (2)*

Both the MIKE FLOOD and MIKE 11 simulations preserve mass, with the amount of flow leaving the system exactly the same as the amount entering. However, the MIKE FLOOD and MIKE 11 simulations each give different distributions between the left and right banks. There are several possible reasons for this:

- MIKE FLOOD accounts for the water level gradient in the channel. This increases the accuracy of over bank flow calculations.
- MIKE FLOOD calculates weir flow across each calculation point (20 in total), whereas the MIKE 11 simulation calculates weir flow at one calculation point.
- It is possible that additional losses from 2D effects (such as eddy formations) in MIKE 21 are contributing to the lateral link structure losses. This may create a variation between a MIKE 11 prediction and the MIKE FLOOD prediction.

The findings of this test show that the lateral links are mass preserving and behave as expected. Further, the test highlights the importance of using lateral links in situations where there is a significant water level gradient in the in-bank river channel.

Finally, an AD simulation is added to the test. To do this, add the AD computation to MIKE 11 and MIKE 21, then set the MIKE FLOOD Coupling Type to be “HD and AD”.

The time series plot displays pollutant concentrations entering the upstream boundary and flowing out the two downstream boundaries:

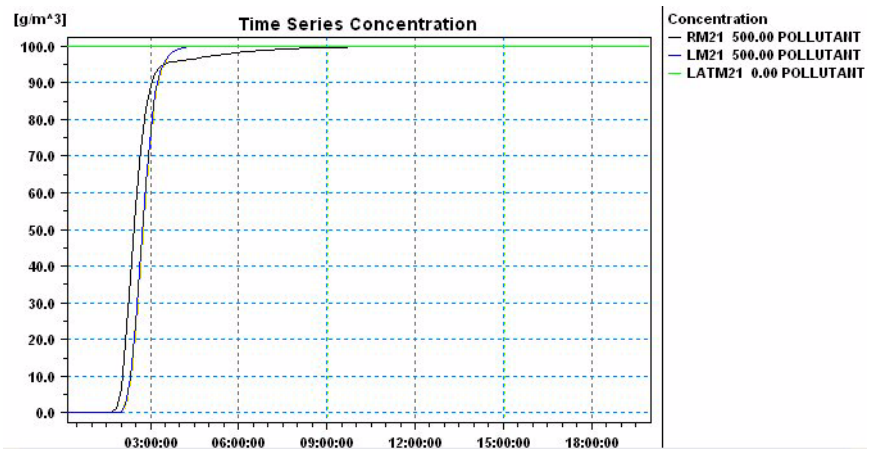



*Figure 8.12 Lateral Link Test 1 Results - Time Series of Concentration*

Also, contour plots of concentration in the MIKE 21 domain are shown at two instances:

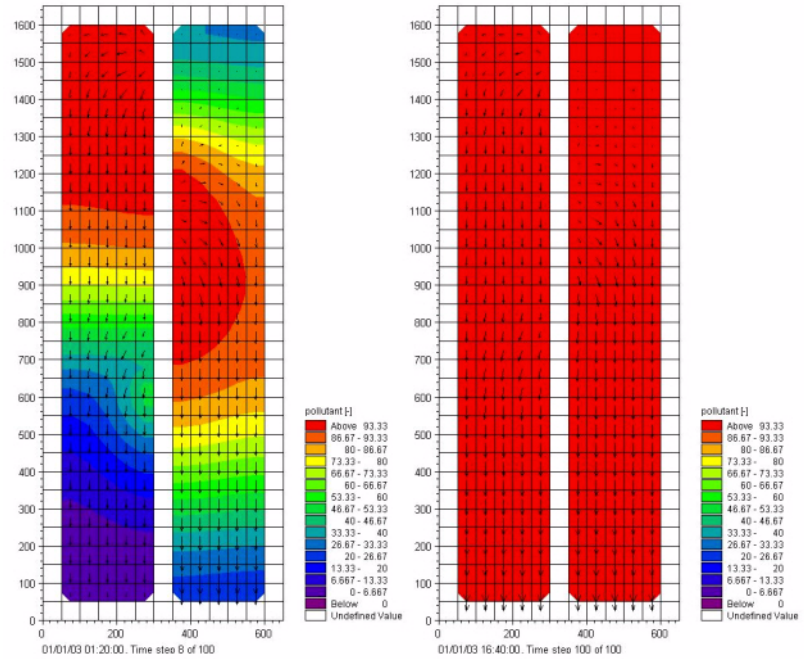



*Figure 8.13 Lateral Link Test 1 Results - Concentration*

## 8.3 Lateral Link 2

This is a test to ensure that the structure equation in the lateral link is consistent with that in a standard MIKE 11 simulation. The first test is a simple MIKE FLOOD model that has a MIKE 11 branch linked to a MIKE 21 basin using a standard link:

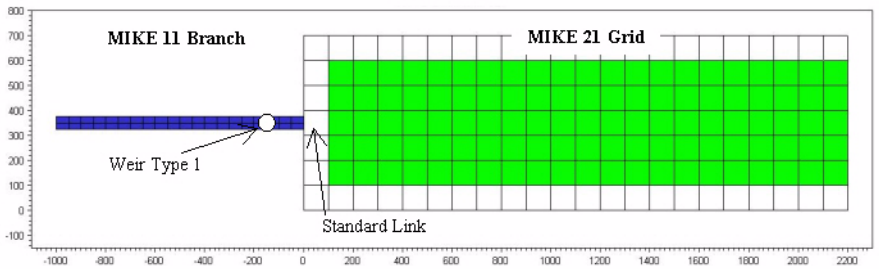



*Figure 8.14 Lateral Link Test 2 - Standard Link Layout*

The MIKE 11 branch is 1000 m long with a uniform cross-section of width 500 and bed level 0 m. The MIKE 21 basin is also 500 m wide with a bed level of 0 m, and is 1000 m long. Grid spacing is 100 m. The MIKE 11 branch has a weir located near the link (chainage 850 m). This weir has a height of 2.2 m and is 500 m wide. A weir formula 1 is applied.

The second test aims to replicate the first, except using a lateral link rather than a standard link. The MIKE 11 branch (branch1) is the same as the first test except it is truncated at the weir location (at chainage 800 m) where another branch (latb) is attached. This branch has a length of 500 m, and the left banks of the cross-sections have a bed level of 2.2 m. The lateral link connects this branch to the MIKE 21 basin. A weir formula 1 is applied in the lateral link.

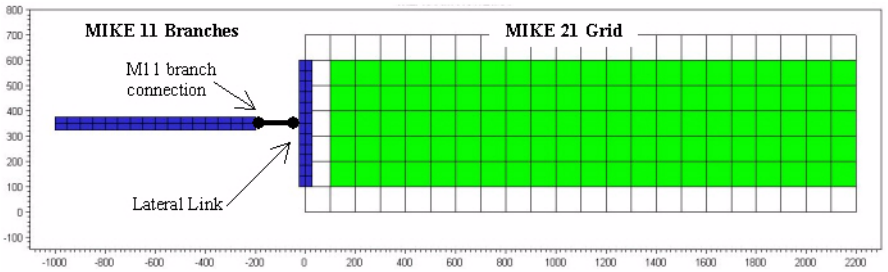



*Figure 8.15 Lateral Link Test 2 - Lateral Link Layout*

The initial water level and the downstream water level at the MIKE 21 boundary is 2 m (so water depth is 2 m in the upstream branch and in the MIKE 21 grid). The simulations are performed using a time step of 30 s (explicit Courant conditions). The upstream flow boundary in MIKE 11 gradually rises from 0 m3/s to 100 m3/s and remains steady at this flow rate.

The resulting water level at the upstream end of the MIKE 11 branch and the discharge at the downstream end are presented below:

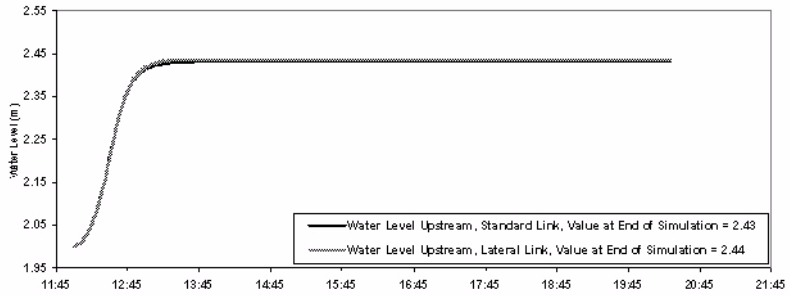



*Figure 8.16 Lateral Link Test 2 Results - Time Series of Water Level*

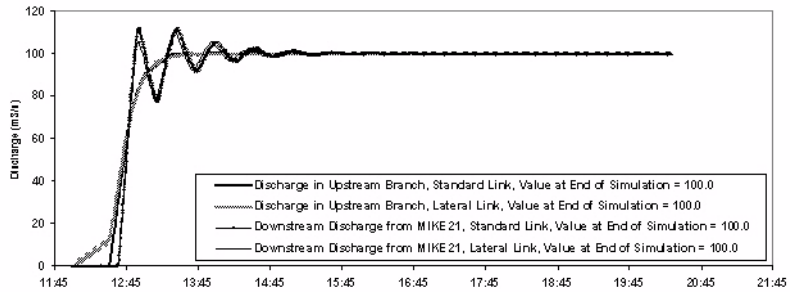



*Figure 8.17 Lateral Link Test 2 Results - Time Series of Discharge*

There is a slight variation in water levels as the discharge increases, but the steady state levels are similar for both simulations (2.43 m and 2.44 m). These variations may be due to the missing momentum transfer across the lateral links. Steady state discharge is the same for both simulations (100 m3/s), indicating that mass is conserved through the links. Notice the oscillations in the discharge at the downstream end of the MIKE 21 basin. This is a result of reflections in the MIKE 21 model, created as the initial wave front produced by the rising discharge enters the MIKE 21 domain.

The water level contours and current vectors in MIKE 21 for each simulation are presented below. Notice that there is a slight variation in flow distributions in the laterally linked case (the variations are shown by the velocity vectors in the link cells).

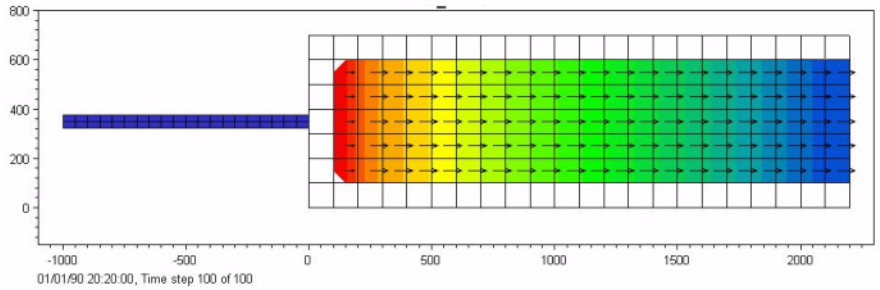



*Figure 8.18 Lateral Link Test 2 Results - Standard Link*

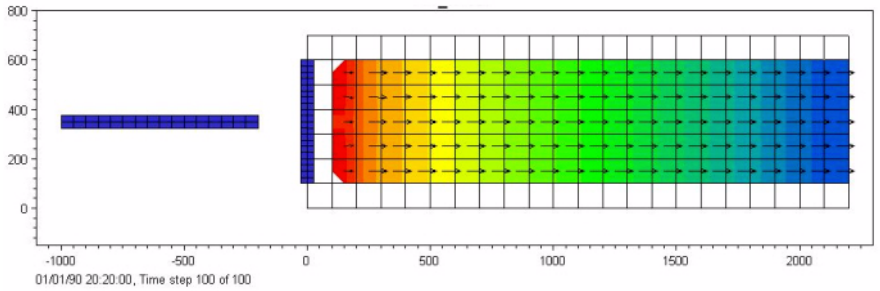



*Figure 8.19 Lateral Link Test 2 Results - Lateral Link*

## 8.4 Flow Direction

This test was initially designed to test links applied in a direction that is not aligned with the MIKE 21 grid. However, it evolved into a demonstration of all the link types available in MIKE FLOOD.

The test consists of a square MIKE 21 basin with a variety of MIKE 11 branches discharging flow into it. The branches are aligned at different angles to the MIKE 21 grid, and consist of standard and lateral links. In the centre of the basin is a lateral link that drains the basin. Using the zero flow links, the bottom right corner has been isolated from the rest of the basin, except for two structure links on each side. The structure links are connected to 3 point MIKE 11 branches with a weir. Some of the link cells in MIKE 21 are completely surrounded by wet cells. Others have land cells, or alternatively zero flow links, inserted behind the link cells.

The MIKE 21 grid size is 10 m and the initial water level is 1 m. A constant discharge of 10 m3/s is applied to the upstream end of each branch, and the time step in both MIKE 11 and MIKE 21 is 2 s.

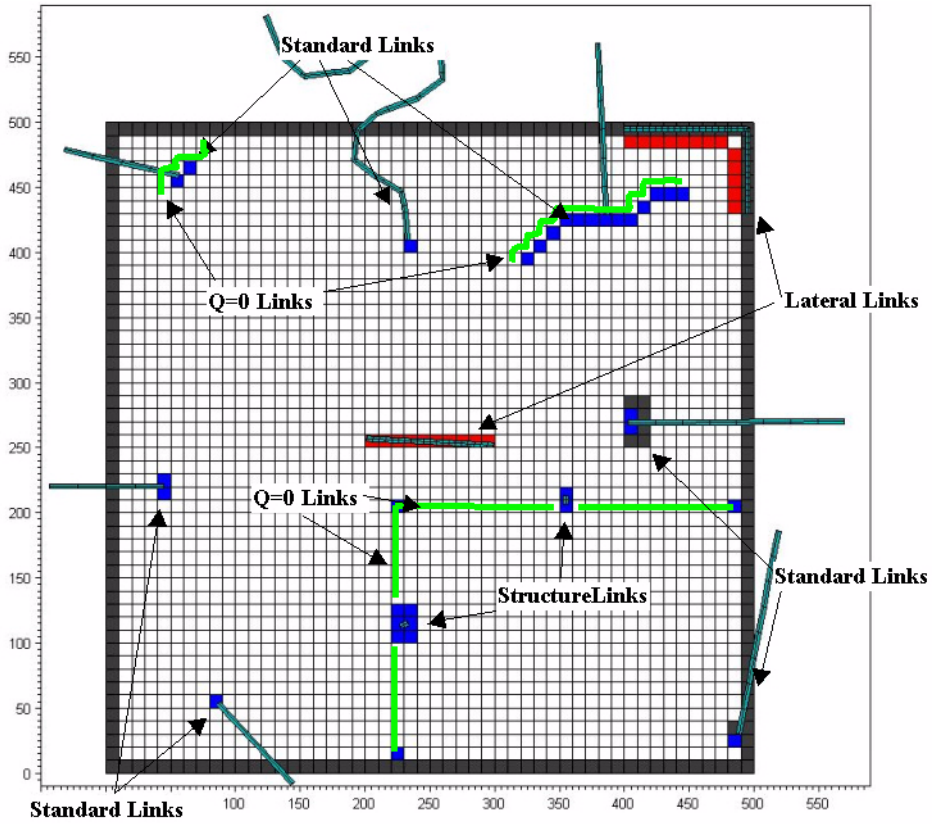



*Figure 8.20 Flow Direction Test Layout*

The HD simulation, run to steady state conditions, is presented below:

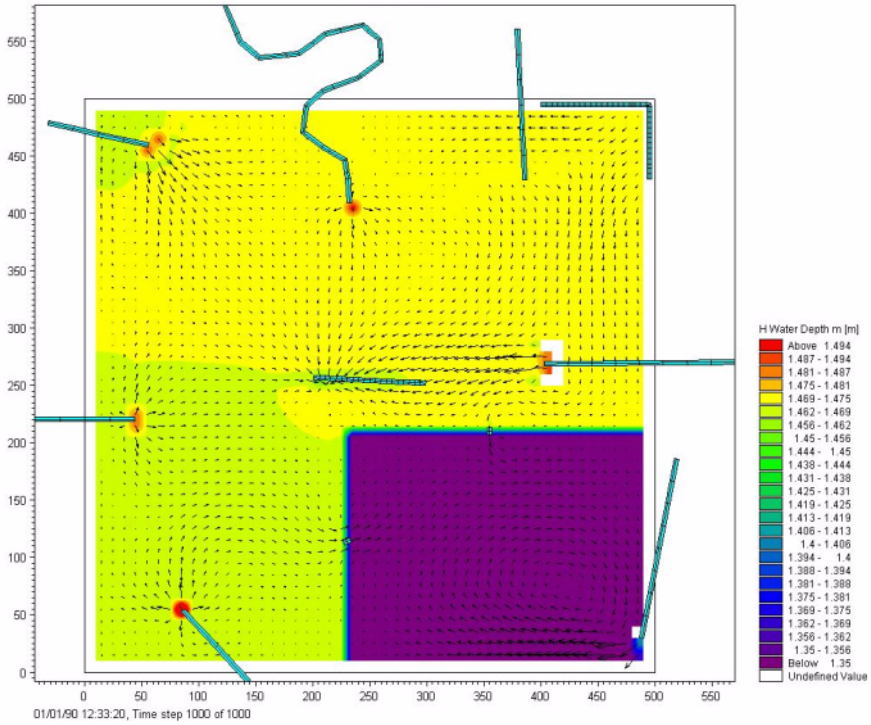



*Figure 8.21 Flow Direction Test Results - Water Depth and Velocity*

As shown, the direction of flow discharging from each linkage point is consistent with the branch alignment. The link points that have land or zero flow links behind them show slightly different flow patterns. As a result of the zero flow links, water levels in the bottom right corner are lower than the rest of the model. This is driving flow through the structure links.

An AD simulation was also performed. Initial concentration was set to zero and inflows apply a conservative concentration of 100. The contour plot below shows results:

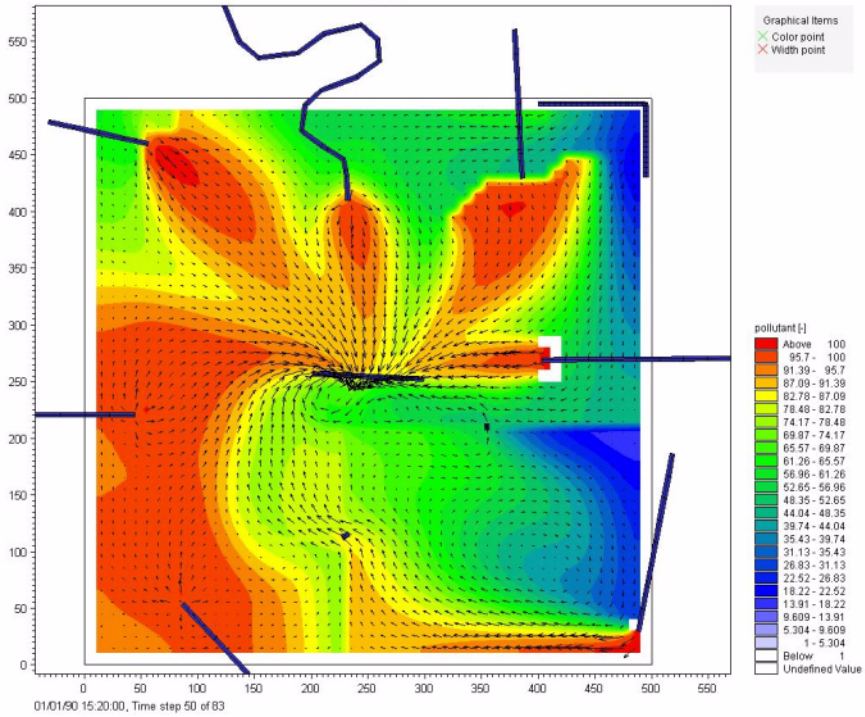



*Figure 8.22 Flow Direction Test Results - Concentration*

The flow directions from the links create a slight “whirlpool” pattern. The zero flow links are also zero concentration links - the plot above demonstrates that the zero flow links are a barrier to advection and dispersion.

Finally, a check of mass conservation in the model is made. With 8 separate inflow branches the total flow rate into the system is 80 m3/s. The resulting discharge through the draining lateral link in the centre of the basin is shown below. At the completion of the simulation, the flow rate shown in MIKE VIEW at the last point in the lateral flow branch is 77 m3/s. While this may appear to be a mass loss error, in fact it is a minor presentation bug caused by having a lateral link at the last h point in the branch. The discharge presented in MIKE VIEW is at the last q point. As lateral flows are added to the h points, this means that the flow rate of 77 m3/s does not include an additional 3 m3/s entering the last h point.

To check this, rerun this simulation with the lateral link connected between chainage 20 to 100 m on the MIKE 11 branch (branch9). The discharge at the last point will then be presented as 80 m3/s, indicating that mass is preserved.

## 8.5 Flood plain Flow

This is another test of the lateral links. It compares model performance over a broad flood plain application. This is a simplified representation of a typical lateral link application - flood plain in MIKE 21, river channel in MIKE 11, and flow between them in MIKE FLOOD.

The test consists of four separate setups:

- MIKE FLOOD -river channel modelled in MIKE 11, footplates in MIKE 21, connected with MIKE FLOOD lateral links (“mf.couple”)
- MIKE 11 - single branch for main channel and footplates (“mf.couple”)
- MIKE 11 - separate main channel and flood plain branches, interconnected by link channels (“mf.couple”)
- MIKE 21 - both river channel and floodplains modelled in MIKE 21 (“m21a.M21”)

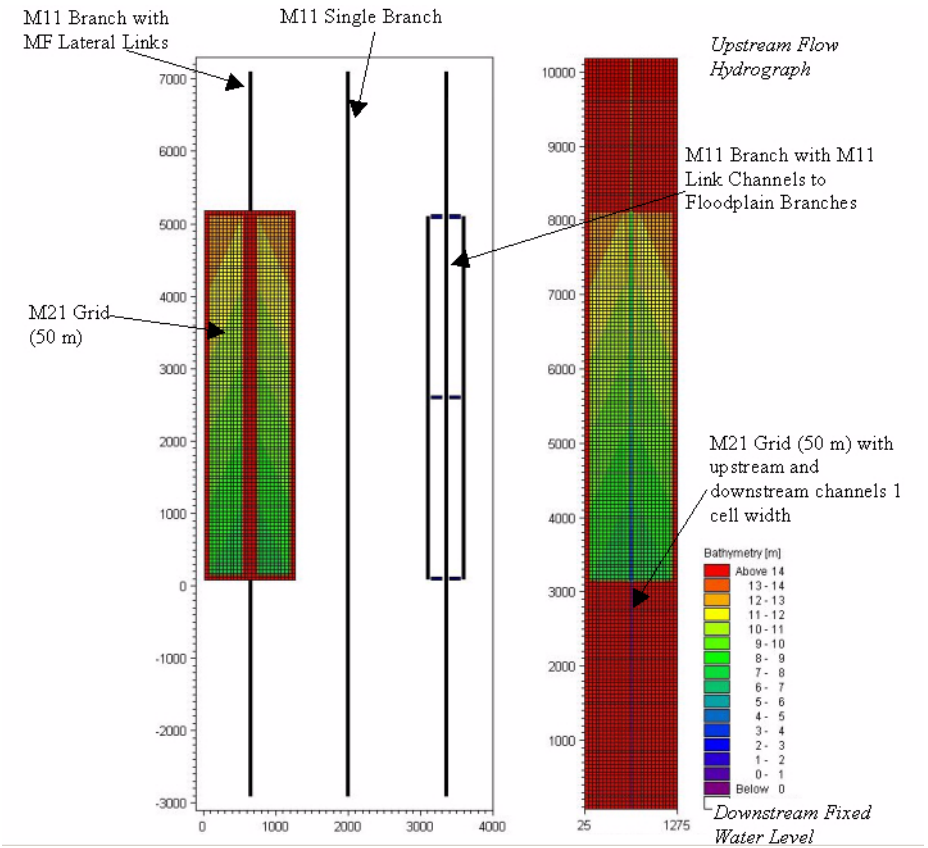



*Figure 8.23 Floodplain Flow Test Layout*

Each test represents the same geometry, consisting of a 50 m wide, 5 m deep channel. On each side of the channel is a 50 m wide levee. Beyond the levees the floodplains are initially 1 m below the levees, and rise laterally by 1 m over a distance of 250 m. A typical cross-section is shown:

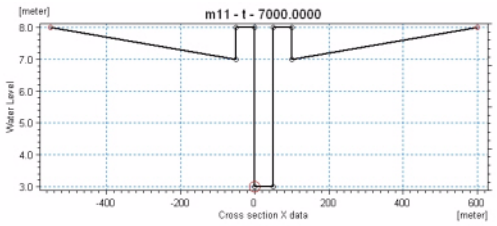



*Figure 8.24 Floodplain Flow Test - Typical Cross-section*

The total length is 10000 m. The river has a uniform slope of 1:1000 - the bed of the main river channel upstream is 10 m, and the bed downstream is 0 m.

To each of these setups, an upstream flow hydrograph is applied, which has a peak discharge of 2000 m3/s. A downstream water depth of 4 m is maintained.

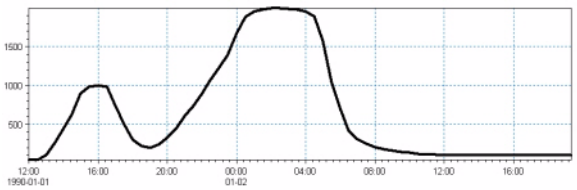



*Figure 8.25 Floodplain Flow Test - Upstream Hydrograph*

The water level at the upstream end of each of the four models is presented:

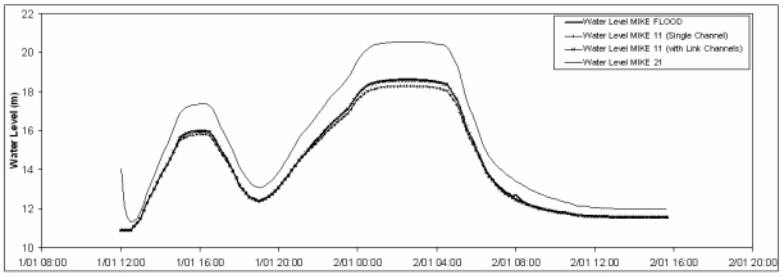



*Figure 8.26 Floodplain Flow Test Results - Upstream Water Level*

Further, the discharge at the downstream ends of each model is presented with the upstream hydrograph:

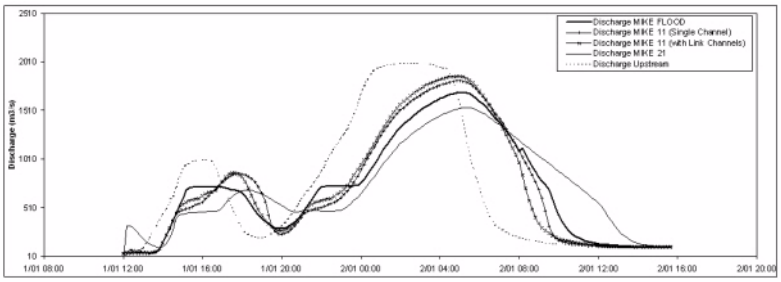



*Figure 8.27 Floodplain Flow Test Results - Downstream Discharge*

For each test case the upstream water levels are reasonably consistent with the other. However, the MIKE 21 simulation predicts a higher water level, suggesting more losses along the length of the model. The downstream discharges are also reasonably consistent, although again the MIKE 21 simulation (and to a lesser extent the MIKE FLOOD simulation) have a reduced, more dampened discharge peak. This again suggests more losses in the model.

A possible reason for this variation in model predictions between MIKE 11 and MIKE 21 could be due to wetting and drying in MIKE 21.

## 8.6 Floodplain Demonstration

This example is available as a demonstration model to illustrate a real application of MIKE FLOOD. The application consists of a flood simulation through a river system. The area of interest is at a confluence with a tributary, where a road embankment has been proposed. Culverts under the road are located on each side of the river.

The river system is represented in MIKE 11. A MIKE 21 grid is inserted into the broader MIKE 11 network to represent flood plain flow, as shown in Figure 8.28:

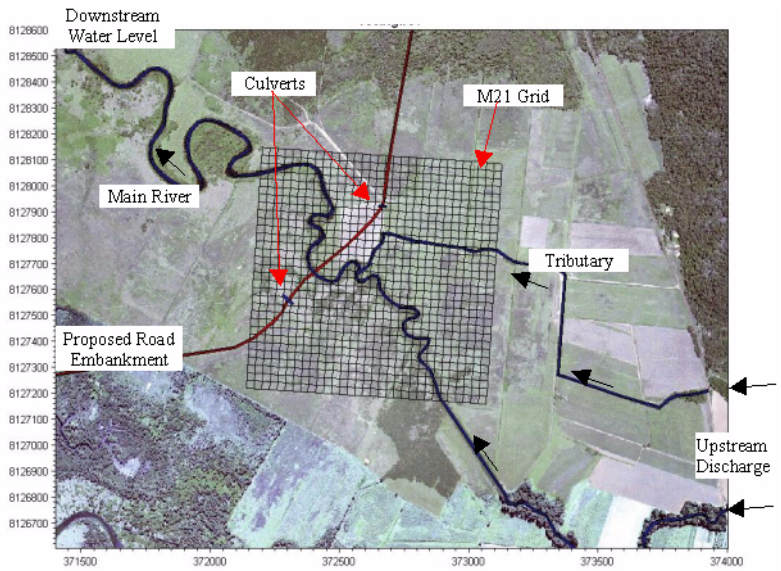



*Figure 8.28 Floodplain Demonstration Layout*

A 5 s time step is used in the simulation and the MIKE 21 grid size is 30 m. The model has been developed with the following MIKE FLOOD links:

- lateral links between the main river channel and floodplain and the tributary and floodplain
- zero flow links along the centre line of the river channel, to ensure that water flows from one side of the floodplain to the other via the main channel
- similarly, zero flow links along the centre line of the tributary
- zero flow links defining the road embankment (assuming that the road does not over top)
- implicit structure links for flow through the culverts

A diagram illustrating the locations of the links is shown:

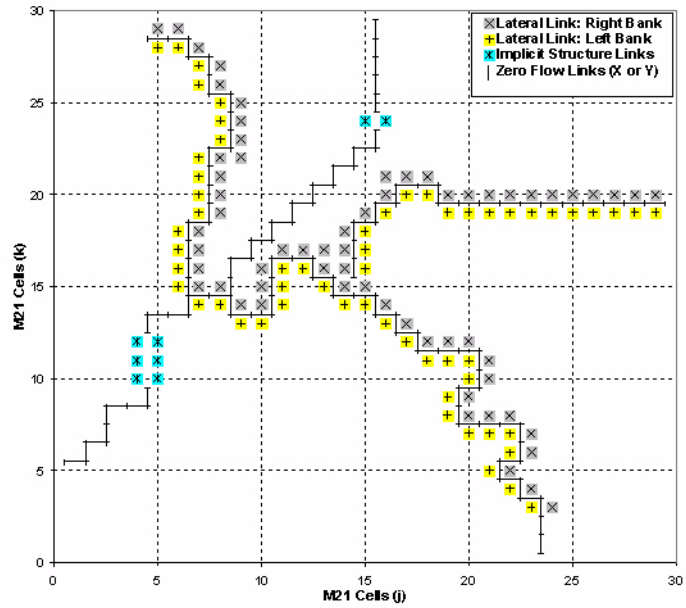



*Figure 8.29 Floodplain Demonstration, Diagram of MIKE FLOOD Links*

The upstream discharge hydrographs for the river and tributary and the downstream water level boundary condition (which is tidal), are shown below:

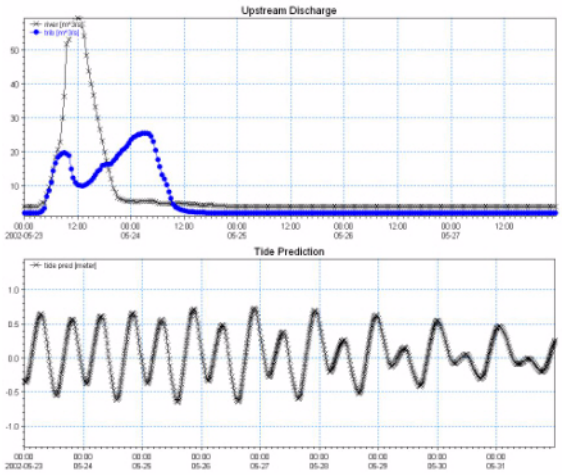



*Figure 8.30 Floodplain Demonstration Boundary Conditions*

Model results showing water surface contours and velocity vectors near the peak of the flood event are presented in Figure 40. The time series

plots in Figure 8.32 show water levels immediately upstream and downstream of the road embankment, and water level difference across the road embankment. Also shown is discharge through the main river channel and through each culvert.

The model results show that for this particular flood event there is a peak 0.36 m head drop across the road embankment. However, the peak head drop at the peak of the flood is 0.16 m. Peak discharge through the main river channel is 44.2 m3/s, which is much higher than the culvert flows of (1.7 m3/s and 3.8 m3/s).

If this model was intended to investigate the hydraulic impacts of the road embankment, a model of the existing situation (no road) could also be performed. Comparing model results with and without the road embankment could give an indication of the likely impacts. Also, the performance of the culverts could be assessed (maybe more are needed?).

Note that this is a demonstration model - not a real example. Other modelling considerations that could be of relevance in this example include:

- The MIKE 21 grid does not cover the entire floodplain width.
- The proposed road crosses over the main channel. Any hydraulic effects (bridge structure or pier losses) created by this situation are ignored.
- The roughness parameter on the floodplain has been set to a constant value of M=20. The roughness may actually be varying spatially, particularly if there are a range of land use patterns.
- The upstream and downstream MIKE 11 branches only represent the main channel. They do not include the flood plains.

The flood plain example is also available as a flexible mesh version. Note that the flexible mesh version does not have zero-flow links available since these may easily be accomplished through the use of internal closed boundaries. The latter has also been done for the flood plain example to model the road cutting through the flood plain.

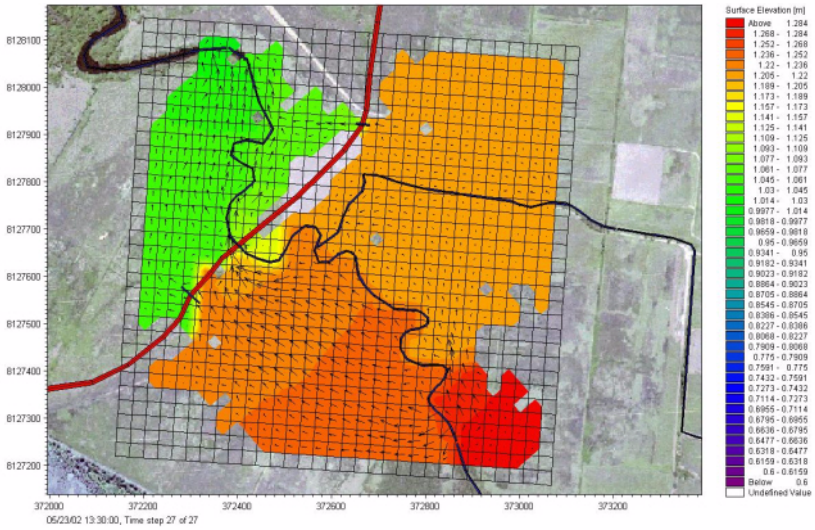



*Figure 8.31 Floodplain Demonstration, Water Surface and Velocities near peak of flood*

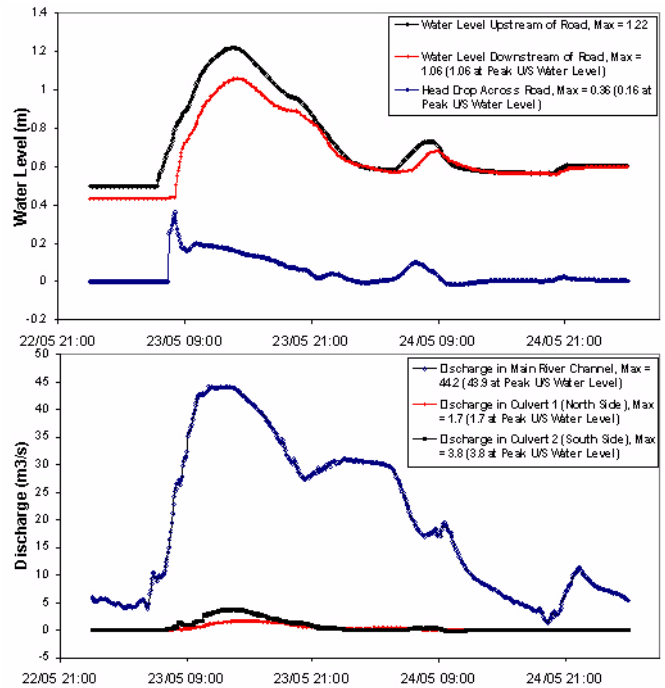



*Figure 8.32 Flood plain Demonstration Results - Water Levels and Flows at Road Embankment.*

## 8.7 Urban examples

Two urban examples are also included with the installation. The first of these urban examples is based on an area in Bangkok and is a reduced model from the full model. The present model represents a sub set of the sewer network and further only couples the 2D and the 1D sewer model at four locations (see Figure 8.33). Note that the example is available both as a MOUSE version and a MIKE URBAN version. The set-up files are located in the folder

DHI\MIKEZero\examples\MIKE_FLOOD\Urban

The example mimics a storm event that results in the sewer system being surcharged causing inundation in the streets.

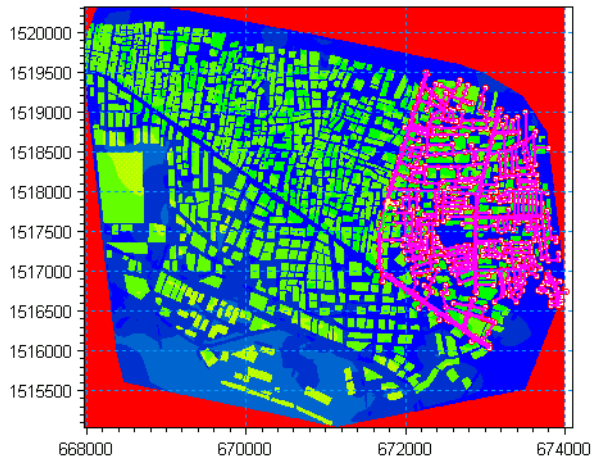



*Figure 8.33 The grid with the sewer system shown in pink.*

HHI Software

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